

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE  
BEFORE THE BOARD OF APPEALS AND INTERFERENCES**

In Re Application of: )  
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Ritsuko NAGAO et al. )  
 )  
Serial No.: 09/768, 133 )  
 )  
Filed: January 23, 2001 )  
 )  
For: Method For Fabricating Display Device )  
 )  
Examiner: Thanh V. Pham )  
 )  
Art Unit: 2823 )

**APPEAL BRIEF UNDER 37 C.F.R. 41.37**

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**APPEAL BRIEF UNDER 37 C.F.R. §41.37**

This Brief is in furtherance of the Notice of Appeal filed in this Application Serial No. 09/768,133 on July 20, 2007.

This appeal is in response to the Final Rejection of March 20, 2007 rejecting all the pending claims.

The claims of the present application are clearly patentable over the cited references, as will be shown *infra*, and Appellant respectfully requests the Board to so rule and allow the application.

**i. STATEMENT OF REAL PARTY IN INTEREST**

The real party in interest in this appeal is the assignee: Semiconductor Energy Laboratory Co., Ltd., 398, Hase, Atsugi-shi, Kanagawa-ken 243-0036 Japan.

**ii. STATEMENT OF RELATED APPEALS AND INTERFERENCES**

Appellant has filed an appeal in related application 10/951,065 on August 23, 2007. Appellant's brief for that appeal was filed on the same day (September 19, 2007) as this brief. The appeal in that case may affect or may be affected by the Board's decision in this case.

To the best of Appellant's knowledge and that of Appellant's legal representatives and the Assignee, there are no other appeals or interferences pending which will affect or be affected by the Board's decision in this appeal.

### **iii. STATUS OF CLAIMS**

Claims 1-10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 31, 33, 35-41, 43-50, 52-59, 61-68, 70-77, 79-86, 88-91, 93-95, 97-101, 103-105, 107-111, 113-115, 117-121, 123-125, 127, 129-131, 133-135, 137, 139-141, 143-145, 147, 149-152, 154-156, 158, 161-164, 166-168, 170, 173-176, 178-180, 182, and 185-205 are pending and rejected. Claims 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 30, 32, 34, 42, 51, 60, 69, 78, 87, 92, 96, 102, 106, 112, 116, 122, 126, 128, 132, 136, 138, 142, 146, 148, 153, 157, 159, 160, 165, 169, 171, 172, 177, 181, 183, and 184 have been canceled.

Claims 1-10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 31, 33, 35-41, 43-50, 52-59, 61-68, 70-77, 79-86, 88-91, 93-95, 97-101, 103-105, 107-111, 113-115, 117-121, 123-125, 127, 129-131, 133-135, 137, 139-141, 143-145, 147, 149-152, 154-156, 158, 161-164, 166-168, 170, 173-176, 178-180, 182, and 185-205 are the appealed claims and appear *infra* at p. 33 *et seq.*

No claims stand allowed.

### **iv. STATUS OF AMENDMENTS**

No amendment after final has been filed in this application.

### **v. SUMMARY OF CLAIMED SUBJECT MATTER**

In accordance with §41.37(c)(v), Appellants are providing the following concise explanation of the claimed subject matter. Appellants are providing examples of where each claim element is shown or discussed in the specification and drawings of the present application. These citations are merely examples, as the application has further disclosure of these elements throughout the application.

The dependent claims are based, either directly or indirectly, on one of the independent claims, and accordingly, all the elements listed for the respective independent claims, and the support for these elements in the specification and drawings are as mentioned herein. These dependent claims also add additional elements or limitations which are supported in the specification and drawings.

#### Claim 1

Independent Claim 1 is directed to a method of fabricating a display device comprising:

forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);

forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);

forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);

forming a silicon nitride film (718) directly formed on the wiring (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) on the silicon nitride film (Fig. 9A, p. 16, lns. 18-21);

forming a second leveling film structure (720) on said first leveling film (Fig. 9B, p. 16, last line – p. 17, ln. 3),

wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3); and

forming a pixel electrode (722) over the second leveling film connecting to the wiring through a second hole (721) formed in the silicon nitride film and the first and second leveling films (Fig. 9C, p. 17, lns. 6-10).<sup>1</sup>

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<sup>1</sup> The references are to the specification as filed. Appellant later filed a substitute specification to correct

### Claim 2

Independent Claim 2 is directed to a method of fabricating a display device comprising the steps of:

- forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);
- forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);
- forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);
- forming a silicon nitride film (718) covering a surface of the wiring (Fig. 9A, p. 16, lns. 4-5);
- forming a first leveling film (719) on the silicon nitride film (Fig. 9B, p. 16, lns. 18-21);
- forming a second leveling film (720) on said first leveling film (Fig. 9B, p. 16, last line – p. 17, ln. 3),
- wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3); and
- forming a pixel electrode (722) over the second leveling film connecting to the wiring through a second hole (721) formed in the silicon nitride film and the first and second leveling films (Fig. 9C, p. 17, lns. 6-10).

### Claim 3

Independent Claim 3 is directed to a method of fabricating a display device comprising the steps of:

- forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12) ;

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informalities in the specification. No new matter was added and the substitute specification was entered and

forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);

forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);

forming a silicon nitride film (718) deposited on the wiring (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) on the silicon nitride film (Fig. 9A, p. 16, lns. 18-21);

forming a second leveling film (720) on said first leveling film Fig. 9B, p. 16, last line – p. 17, ln. 3),

wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3); and

forming a pixel electrode (722) over the second leveling film connecting to the wiring through a second hole (721) formed in the silicon nitride film and the first and second leveling films Fig. 9C, p. 17, lns. 6-10).

#### Claim 4

Independent Claim 4 is directed to a method of fabricating a display device comprising the steps of:

forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);

forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);

forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);

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allowed. Appellant can also provide reference to the substitute specification if the Board so desires.

forming a silicon nitride oxide film (718) directly formed on the wiring (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) on the silicon nitride oxide film (Fig. 9A, p. 16, lns. 18-21);

forming a second leveling film (720) on said first leveling film (Fig. 9B, p. 16, last line – p. 17, ln. 3),

wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3); and

forming a pixel electrode (722) over the second leveling film connecting to the wiring through a second hole (721) formed in the silicon nitride oxide film and the first and second leveling films (Fig. 9C, p. 17, lns. 6-10).

#### Claim 5

Independent Claim 5 is directed to a method of fabricating a display device comprising the steps of:

forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);

forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);

forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);

forming a silicon nitride oxide film (718) covering a surface of the wiring (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) on the silicon nitride oxide film (Fig. 9A, p. 16, lns. 18-

21);

forming a second leveling film (720) on said first leveling film (Fig. 9B, p. 16, last line – p. 17, ln. 3),

wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3); and  
forming a pixel electrode (722) over the second leveling film connecting to the wiring through a second hole (721) formed in the silicon nitride oxide film and the first and second leveling films (Fig. 9C, p. 17, lns. 6-10).

#### Claim 6

Independent Claim 6 is directed to a method of fabricating a display device comprising the steps of:

forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);  
forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);  
forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);  
forming a silicon nitride oxide film (718) deposited on the wiring (Fig. 9A, p. 16, lns. 4-5);  
forming a first leveling film (719) on the silicon nitride oxide film (Fig. 9A, p. 16, lns. 18-21);  
forming a second leveling film (720) on said first leveling film (Fig. 9B, p. 16, last line – p. 17, ln. 3),

wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3); and

forming a pixel electrode (722) over the second leveling film connecting to the wiring through a second hole (721) formed in the silicon nitride oxide film and the first and second leveling films (Fig. 9C, p. 17, lns. 6-10).

#### Claim 7

Independent Claim 7 is directed to a method of fabricating a display device comprising the steps of:

- forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);
- forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);
- forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);
- forming a silicon nitride film (718) directly formed on the wiring (Fig. 9A, p. 16, lns. 4-5);
- forming a first leveling film (719) on the silicon nitride film (Fig. 9A, p. 16, lns. 18-21);
- forming a second leveling film (720) on said first leveling film (Fig. 9B, p. 16, last line – p. 17, ln. 3),
- wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3);
- forming a pixel electrode (722; 4302) connecting the wiring through a second hole (721) in the silicon nitride film and the first and second leveling films over the second leveling film (Fig. 9C, p. 17, lns. 6-10; Fig. 13, p. 20, lns. 17-23); and
- forming an electro luminescence layer (4304) over the pixel electrode (Fig. 13, p. 21, lns. 3-4).

### Claim 8

Independent Claim 8 is directed to a method of fabricating a display device comprising the steps of:

- forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);
- forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);
- forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);
- forming a silicon nitride oxide film (718) directly formed on the wiring (Fig. 9A, p. 16, lns. 4-5);
- forming a first leveling film (719) on the silicon nitride oxide film (Fig. 9A, p. 16, lns. 18-21);
- forming a second leveling film (720) on said first leveling film (Fig. 9B, p. 16, 1st line – p. 17, ln. 3),
- wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3);
- forming a pixel electrode (722; 4302) connecting the wiring through a second hole (721) in the silicon nitride oxide film and the first and second leveling films over the second leveling film (Fig. 9C, p. 17, lns. 6-10; Fig. 13, p. 20, lns. 17-23);
- forming an electro luminescence layer (4304) over the pixel electrode (Fig. 13, p. 21, lns. 2-3); and
- forming a cathode (4305) made of a conductive film having a light-shielding property (Fig. 13, p. 21, lns. 11-14).

### Claim 9

Independent Claim 9 is directed to a method of fabricating a display device comprising the steps of:

forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);

forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);

forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);

forming a silicon nitride oxide film (718) directly formed on the wiring (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) on the silicon nitride oxide film (Fig. 9A, p. 16, lns. 18-21);

forming a second leveling film (720) on said first leveling film (Fig. 9B, p. 16, last line – p. 17, ln. 3),

wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3);

forming a pixel electrode (722; 4302) connecting the wiring through a second hole (721) in the silicon nitride oxide film and the first and second leveling films over the second leveling film (Fig. 9C, p. 17, lns. 6-10; Fig. 13, p. 20, lns. 17-23); and

forming an electro luminescence layer (4304) over the pixel electrode (Fig. 13, p. 21, lns. 3-4).

#### Claim 10

Independent Claim 10 is directed to a method of fabricating a semiconductor device comprising the steps of:

forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);

forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);

forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);

forming a second insulating film (718) comprising a material selected from the group consisting of silicon nitride and silicon nitride oxide directly formed on the wiring (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) formed by a spin coating method on the second insulating film (Fig. 9A, p. 16, lns. 18-21); and

forming a second leveling film (720) by a spin coating method on said first leveling film (Fig. 9B, p. 16, last line – p. 17, ln. 3),

wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3).

#### Claim 31

Independent Claim 31 is directed to a method of fabricating a semiconductor device comprising the steps of:

forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);

forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns.

18-21);

forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);

forming a second insulating film (718) comprising a material selected from the group consisting of silicon nitride and silicon nitride oxide covering a surface of the wiring (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) by a spin coating method on the second insulating film (Fig. 9A, p. 16, lns. 18-21); and

forming a second leveling film (720) by a spin coating method on said first leveling film (Fig. 9B, p. 16, last line - p. 17, ln. 3),

wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3).

### Claim 33

Independent Claim 33 is directed to a method of fabricating a semiconductor device comprising the steps of:

forming a semiconductor film (702-705) over a substrate (700) (Figs. 7A-7D, p. 9-12);

forming an interlayer insulating film (713) over the semiconductor film (Fig. 8C, p. 14, lns. 18-21);

forming a wiring (716, 717) connecting to the semiconductor film through a first hole (714, 715) in the interlayer insulating film on the interlayer insulating film (Fig. 8E, p. 15, lns. 23-24);

forming a second insulating film (718) comprising a material selected from the group consisting of silicon nitride and silicon nitride oxide deposited on the wiring (Fig. 9A, p. 16, lns. 4-

5);

forming a first leveling film (719) by a spin coating method on the second insulating film (Fig. 9A, p. 16, lns. 18-21); and

forming a second leveling film (720) by a spin coating method on said first leveling film (Fig. 9B, p. 16, last line – p. 17, ln. 3),

wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3).

#### Claim 149

Independent Claim 149 is directed to a method of fabricating a semiconductor device comprising the steps of:

forming a wiring (716, 717) on a first insulating film (713) (Fig. 8E, p. 15, lns. 23-24);

forming a second insulating film (718) comprising silicon nitride oxide over said wiring (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) by a spin coating method on the second insulating film (Fig. 9A, p. 16, lns. 18-21); and

forming a second leveling film (720) on the first leveling film by a spin coating method (Fig. 9B, p. 16, last line – p. 17, ln. 3), wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3).

#### Claim 161

Independent Claim 161 is directed to a method of fabricating a semiconductor device comprising the steps of:

forming an insulating film (718) over a wiring (716, 717) (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) by a spin coating method on the insulating film (Fig. 9A, p. 16, lns. 18-21); and

forming a second leveling film (720) on the first leveling film by a spin coating method (Fig. 9B, p. 16, last line – p. 17, ln. 3), wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3).

#### Claim 173

Independent Claim 173 is directed to a method of fabricating a semiconductor device comprising the steps of:

forming a wiring (716, 717) on a first insulating film (713) (Fig. 8E, p. 15, lns. 23-24);

forming a second insulating film (718) comprising silicon nitride over said wiring film (Fig. 9A, p. 16, lns. 4-5);

forming a first leveling film (719) by a spin coating method on the second insulating film (Fig. 9A, lns. 18-21); and

forming a second leveling film (720) on said first leveling film by spin coating (Fig. 9B, p. 16, last line – p. 17, ln. 3), wherein said second leveling film is thicker than said first leveling film (p. 17, lns. 2-3).

#### Dependent Claims

Claims 12, 14, 16, 18, 20, 22, 24, 26 and 28 are dependent on Claims 1-9, respectively, and recite that the display device is used in one selected from the group consisting of a portable phone, a

video camera, a computer, and a projector (**p. 23, ln. 19 - p. 24, last line**).

Claims 35, 44, 53, 62, 71, 80, 89, 99, 109, 119, 129, 139, 150, 162 and 174 are dependent on Claims 1-10, 31, 33, 149, 161 and 173, respectively, and recite that the wiring is formed by a sputtering method (**p. 15, ln. 23 - p. 16, ln. 3**).

Claims 36, 45, 54, 63, 72, 81, 90, 100, 110, 120, 130, 140, 151, 163 and 175 are dependent on Claims 1-10, 31, 33, 149, 161, and 173, respectively, and recite that the wiring comprises aluminum (**p. 15, last line - p. 16, ln. 1**).

Claims 37, 46, 55, 64, 73, 82, 91, 101, 111, 121, 131, 141, 152, 164 and 176, are dependent on Claims 1-10, 31, 33, 149, 161 and 173, respectively, and recite that the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film (**p. 15, last line – p. 16, ln. 3**).

Claims 38, 47, 56, 65, 74 and 83, are dependent on Claims 1-6, respectively, and recite that the display device is a liquid crystal display device or an electro luminescence display device (**p. 23, lns. 7-17**).

Claims 39, 48, 57, 66, 75, 84, 93, 103 and 113, are dependent on Claims 1-9, respectively, and recite that the silicon nitride film has a thickness of 50 to 500nm (**p. 16, lns. 4-5**).

Claims 40, 49, 58, 67, 76, 85, 94, 104 and 114, are dependent on Claims 1-9, respectively, and recite that the silicon nitride film has a thickness of 200 to 300nm **(p. 16, lns. 4-5)**.

Claims 41, 50, 59, 68, 77, 86, 95, 105, 115, 125, 135, 145, 156, 168 and 180, depend on Claims 1-10, 31, 33, 149, 161 and 173, respectively, and recite that the first leveling film has a thickness of 0.1  $\mu\text{m}$  to 1.5  $\mu\text{m}$  **(p. 7, lns. 1-3)**.

Claims 43, 52, 61, 70, 79, 88, 98, 108 and 118 are dependent on Claims 1-9, respectively, and recite that the pixel electrode is made of a conductive oxide film **(p. 17, lns. 10-15)**.

Claims 97, 107 and 117, are dependent on Claims 7-9, respectively, and recite that the second hole is formed by a dry etching method **(p. 17, lns. 6-8)**.

Claims 123, 133, 143, 154, 166 and 178, are dependent on Claims 10, 31, 33, 149, 161 and 173, respectively, and recite that the second insulating film has a thickness of 50 to 500nm **(p. 16, lns. 4-5)**.

Claims 124, 134, 144, 155, 167 and 179, are dependent on Claims 10, 31, 33, 149, 166 and 173, respectively, and recite that the second insulating film has a thickness of 200 to 300nm **(p. 16, lns. 4-5)**.

Claims 127, 137, 147, 158, 170 and 182, are dependent on Claims 10, 31, 33, 149, 161 and 173, respectively, and recite that each of the first and second leveling films comprises an inorganic

spin on glass material **(p. 16, ln. 18 - p. 17, ln. 3; p. 18, lns. 4-5).**

Claims 185, 187, 189, 191, 193 and 195, are dependent on Claims 10, 31, 33, 149, 161 and 173, respectively, and recite that each of said first and second leveling films comprises a resin **(p. 18, lns. 4-5).**

Claims 186, 188, 190, 192, 194 and 196, are dependent on Claims 10, 31, 33, 149, 161 and 173, respectively, and recite that each of said first and second leveling films comprises a material selected from the group consisting of phosphosilicate glass, borosilicate glass and borophosphosilicate glass **(p. 7, lns. 9-13).**

Claims 197-205, are dependent on Claims 1-9, respectively, and recite that said first and second leveling films contain a siloxane structure **(p. 18, lns. 4-5).**

## **vi. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL**

The following are the grounds for rejection presented for review:

In the Final Rejection, the Examiner rejects Claims 1-10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 31, 33, 35-41, 43-50, 52-59, 61-68, 70-77, 79-86, 88-91, 93-95, 97-101, 103-105, 107-111, 113-115, 117-121, 123-125, 127, 129-131, 133-135, 137, 139-141, 143-145, 147, 149-152, 154-156, 158, 161-164, 166-168, 170, 173-176, 178-180, 182, and 185-205 under 35 USC §103(a) as being unpatentable over “applicant's admitted prior art” in combination with Chen (U.S. 5,453,406), Tang et al. (US 5,550,066) and Hanihara et al. (US 5,990,988).

## **vii. ARGUMENT**

### **A. BACKGROUND**

The present invention is directed to a method of fabricating a display device. The method includes the steps, among other steps, of forming a silicon nitride film on a wiring, forming a first leveling film on the silicon nitride film, and forming a second leveling film on the first leveling film.

The second leveling film is thicker than the first leveling film. As explained on pages 3-7 of the specification of the present application, the inventors have discovered a number of unique and unexpected results by having the second leveling film thicker than the first leveling film, such as for example improving leveling rate. In addition, the total thickness of the leveling film required for achieving a certain leveling rate can be reduced as compared with a method where the first leveling film is thicker than the second leveling film, as in Chen (U.S. 5,453,406; discussed *infra*). By reducing the total thickness of the leveling film, an etching process on the leveling film for forming a

through hole therein can be performed much more easily, and as a result, reliability and productivity are improved.

More specifically, as shown in Fig. 5 in the present application, in case of a single leveling film, with an increase in a thickness of the leveling film, the leveling rate also increases (e.g. page 5, lns. 12-13 in the specification of the present application). However, there is a limit in increasing the thickness of the leveling film (e.g. page 4, lns. 12-15).

Further, in the case of laminating a plurality of leveling films, the leveling rate is higher with the laminated layers than with a single layer where the same total thickness is achieved (e.g. page 5, last line – page 6, ln. 3). Furthermore, as shown in Fig. 6, in the case of laminating first and second leveling films, a higher leveling rate can be realized by setting a thickness  $T_1$  of the first leveling film smaller than a thickness  $T_2$  of the second leveling film where the value of  $T_1 + T_2$  is constant (e.g. page 6, lns. 9-11). In other words, the total thickness of the leveling films can be smaller by setting  $T_1$  smaller than  $T_2$  (as compared to the thickness of a single leveling film and the total thickness of the leveling films when setting  $T_1$  larger than  $T_2$ ), in accordance with the present invention.

In addition, the flatness of a pixel electrode is becoming more important for a pixel electrode to improve display quality. Chen teaches to form two leveling layers for providing a leveled upper surface, but Chen does not teach that the second layer should be thicker than the first or lower layer. The present inventor(s) wanted to improve the leveling rate especially for a pixel electrode and found that the leveling layer can be more improved by making the second layer thicker than the first layer. As explained *infra*, Chen is not relevant to a pixel electrode and appears to be opposite to the claimed invention.

Therefore, the claimed feature of having a second leveling film thicker than a first leveling film is advantageous and provides unique and unexpected results.

As shown in detail in Section B *infra*, this claimed feature is not present in the cited references.

Appellant will now address the sole rejection of the claims in the Final Rejection of March 20, 2007.

**B. THE §103 REJECTION OF THE CLAIMS SHOULD BE REVERSED**

In the Final Rejection, the Examiner rejects Claims 1-10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 31, 33, 35-41, 43-50, 52-59, 61-68, 70-77, 79-86, 88-91, 93-95, 97-101, 103-105, 107-111, 113-115, 117-121, 123-125, 127, 129-131, 133-135, 137, 139-141, 143-145, 147, 149-152, 154-156, 158, 161-164, 166-168, 170, 173-176, 178-180, 182, and 185-205 under 35 USC §103(a) as being unpatentable over “applicant’s admitted prior art” in combination with Chen (U.S. 5,453,406), Tang et al. (US 5,550,066) and Hanihara et al. (US 5,990,988). Appellant respectfully submits that this rejection is improper as a prima facie case of obviousness has not been established, the rejection is based on improper hindsight reconstruction, and any case of obviousness by the Examiner has clearly been rebutted.

As explained in MPEP §2142, the burden is initially on the Examiner to establish a prima facie case of obviousness. If the Examiner does not establish a prima facie case, then the rejection is improper and should be withdrawn. To establish a prima facie case of obviousness, MPEP §2142 and 2143 state that:

“To establish a prima facie case of obviousness, three basic criteria must be met... Finally, the prior art reference (or references when combined)

must teach or suggest all the claim limitations.” (emphasis added).

A prima facie case of obviousness cannot be based on hindsight reconstruction using the claimed invention as a template. In re Fritch, 972 F.2d 1260, 1266, 23 USPQ2d 1780, 1784 (Fed. Cir. 1992); In re Oetiker, 24 USPQ 2d 1443, 1447 (Fed. Cir. 1992). Cf. Dennison Mfg. Co. v. Panduit Corp., 475 U.S. 809, 810, 106 S. Ct. 1578 (1986); KSR Int’l Co. v. Teleflex, Inc., No. 04-1350, slip opinion at p. 15, 107 S. Ct. 1727, 82 USPQ2d 1385 (U.S. April 30, 2007).

As will be explained below, in this case, the references do not teach or suggest all the claim limitations, there is no reason why a person of ordinary skill in the art would have changed the process as reflected in the claims, the Examiner has improperly relied upon hindsight reconstruction to reject the claims, and the Examiner’s obviousness case has clearly been rebutted. Therefore, the rejection based thereon must be reversed.

#### The §103 Rejection Is Improper

In particular, independent Claims 1-10, 31, 33, 149, 161 and 173 specifically recite the steps of forming first and second leveling films and the feature that the second leveling film is thicker than the first leveling film. As explained in the specification of the present application and the Background herein, this feature provides a number of unique and unexpected results and is highly advantageous for leveling the surface over a wiring. See e.g. pages 3 – 7 and 17 of the specification and Figs. 5 and 6 explaining the advantages achieved by the present inventors through their conception of the present invention wherein the second leveling film is thicker than the first leveling film. For at least the reasons explained in the specification, this is a non-obvious discovery which is highly advantageous and is not a matter of routine experimentation.

In the Final Rejection, the Examiner admits that “applicant’s admitted prior art” does not show (“lacks”) the second leveling layer over the first leveling layer and wherein the second leveling is thicker than the first leveling film. The Examiner, however, relies only upon Chen for allegedly showing this feature and cites Chen as showing a second leveling layer 42 over a first leveling layer 40 and contends that Chen teaches that the thickness of the first leveling film 40 is 2000 to 3000 Angstroms (citing Chen, col. 6, lns. 1-10) and is thinner than the thickness of the second leveling film 42 (which the Examiner contends is 4000 to 6000 Angstroms, citing Chen, col. 6, lns. 53-54). The Examiner then states that both first and second leveling films are formed by spin coating, citing Col. 6, ln. 30 in Chen.

However, the Examiner’s interpretation of Chen is technically incorrect. One skilled in the art would not interpret Chen in the manner that the Examiner has interpreted Chen. The only other possible interpretation is that Chen is completely vague as to the thicknesses of the two films, and there is no disclosure in Chen as to the relative thicknesses of these two films.

For example, at col. 6, lns. 25-55, Chen states:

Referring next to FIG. 7, a *second spin-on-glass layer 42* is now formed over the first spin-on-glass layer 40 essentially planarizing the dielectric layer and completing the process. This second spin-on-glass *layer 42 is formed* by also using the liquid precursor of the siloxane type *similar in composition to the material used for the first spin-on-glass layer 40, but in this second coating the spin-on-glass is dispensed at a significantly higher spin speed* and at a constant speed. The *same series of spin-on-glass is used for both layers*.

The substrate is again placed on a spin coater and brought to a constant rotational speed in the range of about 2500 to 3000 revolutions per minute (rpm) before dispensing the spin-on-glass and then the substrate is maintained at this constant rotational speed for an additional 6 seconds. The substrate is then brought to a stationary position, that is the spin speed is reduced to zero rpm and the second

spin-on-glass layer is allowed to air dry at room temperature of about 25°C for an additional 15 seconds. The substrate is then baked, for example on a hot plate, at a temperature of between about 100° to 300°C for a time of between about 0.5 to 2.0 minutes. The spin-on-glass layer 42 is then pyrolyzed at a relatively high temperature to form an inorganic glass. The preferred curing temperature for this last step is between about 400° to 450°C and for a time of about 20 to 30 minutes, and more specifically at a temperature of 425°C for 30 minutes thereby forming the inorganic glass. *The preferred thickness of layer 42 is between about 4000 to 6000 Angstroms* as can be seen in FIG. 7, the spin-on-glass dielectric layer fills the recesses and essentially planarizes the irregular recesses or gaps on the substrate. (emphasis added)

Hence, from this section, Chen appears to teach that preferably layer 42 has a thickness between about 4000 to 6000 Angstroms, and that the spin-on-glass used to form layer 42 is dispensed at a significantly higher speed (i.e. 2500 to 3000 rpm) than the speed for dispensing the first layer 40.

At Col. 6, lns. 10-24, Chen states:

Referring now more particularly to the method of coating the substrate to form the planarizing dielectric layer over the patterned conducting layer, a first spin-on-glass *coating 40, is formed by* first bringing the substrate to a constant rotational speed in the range of about 600 to 800 revolutions per minute (rpm) and then dispensing the spin-on-glass liquid precursor for about 6 seconds. The spin-on-glass is then allowed to air dry at room temperature of about 25°C for another 15 second at the above constant rotational speed. The substrate is then removed from the spin coater and baked, for example on a hot plate, at a temperature of between about 100 to 300 for a time of between 0.5 to 2.0 minutes. Because of this lower and constant spin speed the recesses or gaps between the patterned conductor 34 fill more evenly, as was depicted earlier in FIGS. 3A and 3B. (emphasis added)

Hence, from this section, Chen clearly teaches that (first) layer 40 is formed at a rotational speed of about 600 to 800 rpm. This is significantly less than the speed used to form (second) layer 42, as shown above. This section does not recite any specifics as to the actual thickness of layer 40.

It is believed that one skilled in the art, however, would clearly understand from the two above passages that first layer 40 in Chen must be thicker than second layer 42. More specifically, if the same materials are used for layers 40 and 42 (which they may be in Chen<sup>2</sup>), then it is well known in the art that the thickness of a spin coated film *decreases* as the rotational speed *increases*, i.e. the faster the rotational speed, the thinner the layer. In support thereof, Appellant submitted an article, Dietrich Meyerhofer, "Characteristics of resist films produced by spinning," J. Appl. Phys. 49(7), July 1978, p. 3993-3997, with the Response (M) to the Office Action and the IDS filed August 16, 2006, and which is of record in this application. Figs. 2 and 4 in Meyerhofer clearly demonstrate that the greater the spin speed (in rpm), the thinner the film thickness.

Accordingly, if layers 40 and 42 in Chen are formed of the same materials and since layer 42 is being applied at a spin speed significantly higher than that of layer 40, layer 42 (the alleged second layer) must be thinner than layer 40 (the alleged first layer). If layers 40 and 42 are formed of similar materials (not the same materials), at the very least, Appellant asserts that the *thickness of layer 40 is not taught or suggested by Chen*. One skilled in the art would clearly appreciate these points.

Further, in the Final Rejection, the Examiner now states that "[i]n Chen's fig. 7, the first 'leveling' layer 40 in the trenches is clearly thicker than the second 'leveling' layer 42 directly upon it." Pages 6 and 11 of the Final Rejection. This admission seems to clearly support Appellant's position.

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<sup>2</sup> It is noted that col. 6, lns. 25-55 in Chen state that layer 42 is formed by using "the liquid precursor of the siloxane type *similar* in composition to the material used for the first spin-on-glass layer 40" and "[t]he *same* series of spin-on-glass is used for both layers" (emphasis added). However, as explained above, whether it is the same or similar material, Chen **does not teach the specific thickness of layer 40** and does not disclose or suggest the claimed method of the present application.

In contrast to Chen, independent Claims 1-10, 31, 33, 149, 161, and 173 of the present application specifically recite that the second leveling film is thicker than the first leveling film. Hence, as the Examiner admits at pages 6 and 11 of the Final Rejection, Chen appears to teach the opposite of this claimed feature.

The Examiner also cites to col. 5, ln. 61 - col. 6, ln. 24 in Chen which the Examiner contends teaches the formation of the first spin-on-glass layer 40 as having a thickness of 2000-3000 Angstroms and as a result being thinner than layer 42. Appellant respectfully submits that the Examiner's interpretation of this section in Chen is technically incorrect and one skilled in the art would not interpret this passage in the same manner as the Examiner.

In particular, col. 5, line 62 to col. 6, line 9 in Chen states:

“Now referring to FIG. 6, a first spin-on-glass layer 40 is formed over the insulating layer 36 by spin coating. The preferred material used is a spin-on-glass liquid which consist of a silicon-oxide (Si--O) network polymer dissolved in a common organic solvent, such as alcohol, ketones and esters. And more specifically the preferred spin-on-glass material is a series of siloxane base material marketed by the Allied-Signal Corp. under the trade name ACCUGLASS. The preferred material in the series being ACCUGLASS 211, 314 or 311. The primary difference between the spin-on-glass types is the viscosity (solid content). For example, the series 211 has a lower viscosity and produces a thinner coating of about 2000 Angstroms while series 314 and 311 have a higher viscosity and produce coatings of about 3000 Angstroms.” (emphasis added)

In this section, Chen is merely discussing the primary difference between ACCUGLASS 211, 314 or 311, not the thickness of layer 40. This discussion is consistent with the materials provided by Honeywell regarding the Accuglass 211 and 311.<sup>3</sup> As shown in the literature from Honeywell<sup>4</sup>,

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<sup>3</sup> As shown in the materials of record and attached to Response (M) filed August 16, 2006, the trademark for Accuglass is currently owned by Honeywell. Honeywell received this trademark from

Accuglass 211 has a thickness of approximately 2000 Angstroms *at a spin speed of 3000 rpm*, while Accuglass 311 has a thickness of approximately 3000 Angstroms *at a spin speed of 3000 rpm*. Further, the literature shows that *at slower spin speeds*, both Accuglass 211 and Accuglass 311 have higher thicknesses.

Therefore, at a spin speed of 600 to 800 rpm as taught in Chen, (first) layer 40 of Accuglass 211 or 311 would have a thickness higher than the thickness of (second) layer 42 of Accuglass 211 or 311 at a spin speed of 2500 to 3000 rpm.

Hence, the passage at col. 5, line 62 to col. 6, line 9 in Chen does not support the Examiner's contention that the actual thickness of layer 40 is between 2000-3000 Angstroms. Instead, this passage merely discusses the differences between these materials (i.e. Accuglass 211 v. Accuglass 311); and if the two films are formed at the same speed, because of the differences in starting materials, a film formed from the series 211 is about 2000 Angstroms and a film formed from the series 311 or 314 is about 3000 Angstroms. As explained above, there is *no specific disclosure* in Chen as to the thickness of layer 40, other than what one skilled in the art could interpret based on the spin speed, and such an interpretation would have to conclude that (first) layer 40 is thicker than (second) layer 42.

As explained above, the Examiner's conclusion that layer 40 is 2000 – 3000 Angstroms is directly in contrast to the teachings in Chen that layer 40 is formed at a slower spin speed than layer 42 (and therefore layer 40 must be thicker) and that layer 42 has a thickness between 4000 – 6000 Angstroms.

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AlliedSignal as the result of a merger.

<sup>4</sup> This literature is of record and was attached to Response (M) and IDS filed August 16, 2006 in this application.

Therefore, Chen does not disclose or suggest the claimed feature of the present application of wherein said second leveling film is thicker than said first leveling film.

The Examiner also contends that it would be a routine matter of experimentation as to choice of thickness layers. However, as explained above, Chen appears to teach to those skilled in the art, based on the various rotation speeds recited in the reference, that the first layer 40 is thicker than the second layer 42. There is no disclosure or suggestion in Chen of the reverse configuration and nothing to suggest this is a matter of routine experimentation.

Importantly, there is no reason for one skilled in the art to make the Examiner's alleged modifications to Chen. As established in KSR, there must be a reason to make the proposed modification. As explained *supra*, one of the results of the claimed invention related to improving quality of the pixel electrode. However, there is no disclosure in Chen of a pixel electrode, and the teachings in Chen do not appear to be relevant to a pixel electrode. Further, the teachings in Chen are opposite of the claimed invention, as discussed *supra*. Hence, there is no reason to make the Examiner's proposed modification.

Alternatively, if one skilled in the art were to follow the various conflicting citations in Chen, some of which the Examiner relies upon, some of which he disregards, the only other possible conclusion is that the disclosure in Chen is simply unreliable and unclear on the actual and relative thickness of the two layers. The teachings in the reference regarding such thicknesses are at best confusing and contradictory. As a result, one skilled in the art reading this reference would not have confidently arrived at any conclusion as to the actual thicknesses of the two layers. Hence, there is nothing in Chen to suggest the claimed method of the present application or to suggest that the claimed method is merely routine experimentation. Instead, by reciting the specific spinning speeds

above, Chen appears to be teaching away from the configuration of the claimed invention.

None of the other cited references disclose this claimed feature. There is no reason to expect that leveling can be improved as set forth herein by controlling the second layer thickness, as in the claimed invention.

Further, the Examiner's entire argument appears to be based on hindsight reconstruction. The Examiner has taken the claimed thicknesses of the leveling films and has picked and chosen isolated portions of Chen (while disregarding other teachings) to allegedly read on the claimed thicknesses. However, it is improper to pick and choose among isolated disclosures to deprecate the claimed invention. In re Fine, 837 F.2d 1071, 1074, 5 USPQ2d 1596, 1600 (Fed. Cir. 1988); Bausch & Lomb, Inc. v. Barnes-Hind/Hydrocurve, Inc., 796 F.2d 443, 448, 230 USPQ 416, 419-420 (Fed. Cir. 1986). To do so is to engage in hindsight reconstruction which is improper. Id.

The Supreme Court cautions against such hindsight. Dennison Mfg. Co. v. Panduit Corp., 475 U.S. 809, 810, 106 S. Ct. 1578 (1986) ("...in addressing the question of obviousness a judge must not pick and choose isolated elements from the prior art and combine them so as to yield the invention in question of such a combination would not have been obvious at the time of the invention"); KSR, slip opinion at 17, 107 S. Ct. at 1742 (be aware of distortion caused by hindsight bias and be cautious of *ex post* reasoning). This prohibition continues to be valid under the recent Supreme Court case, KSR Int'l Co. v. Teleflex, Inc. Such a hindsight technique is still improper and differs from the use of common sense referenced in KSR. It is still the law that the Examiner must consider the entire teaching in the references and cannot pick and choose among isolated teachings in the references to the exclusion of the other teachings in the reference. Bausch & Lomb, Inc. v. Barnes-Hind/Hydrocurve, Inc., 796 F.2d 443, 230 USPQ 416, 419-420 (Fed. Cir. 1986). To consider

less than the entire teaching is to engage in improper hindsight reconstruction. Id. Such an analysis would clearly not be based on common sense.

Instead, the reference must be considered in its entirety. Fine, 837 F.2d at 1074, 5 USPQ2d at 1600. When considered in its entirety, one skilled in the art would conclude, based on the disclosure of spinning speeds, that layer 40 (the first leveling layer) is thicker than layer 42 (the second leveling layer) or would have to conclude that Chen is vague and unclear and does not teach the relative thicknesses of the two layers.

Hence, independent Claims 1-10, 31, 33, 149, 161 and 173 and those claims dependent thereon are not disclosed or suggested by the cited references could not result from common sense, are unexpected and improved, and are patentable over the art.

In the Response to Arguments, the Examiner raises additional points in reply to Appellants' prior Response.

At page 9 of the Final Rejection, the Examiner appears to be taking the position that the claimed dimensions do not produce an unexpected result nor do they appear to be critical, and therefore are prima facie obvious. Appellant respectfully disagrees.

As explained *supra*, the claimed dimensions produce a number of advantages, such as for example, improved leveling rate, reduction in total thickness of the leveling film which makes etching easier,<sup>4</sup> and improvements in reliability and productivity. Hence, this objection by the Examiner is baseless and should be withdrawn.

Further, it is noted that the Examiner agrees with Appellant that "if all the other conditions/parameters/variables besides spinning speeds are kept the same, Appellant's argument(s) is(are) agreed." See page 10 of the Final Rejection. The Examiner, however, contends that "a

crucial factor is missing/changed.”

In particular, the Examiner appears to disagree with Appellants’ position because the Examiner alleges that the conditions for the formation of the first layer 40 in Chen were not identical to the conditions for the formation of the second layer 42. More specifically, the Examiner appears to now be contending that the formation of the first layer 40 in Chen has an air dry step which includes a rotation for 15 seconds and that this makes the first layer thinner than the second layer because the air dry step of the second layer 42 is performed without a rotation. This difference, however, does not seem to provide any direct support for the Examiner’s contention that the second layer 42 is allegedly thicker than the first layer 40 since Chen explicitly states that the spin speed is significantly higher for the second spin coating of the second layer 42 (leading to the first layer 40 being thicker). See e.g. Col. 6, lines 22-25 in Chen.

Moreover, Claims 3-6 in Chen show that this argument by the Examiner is clearly erroneous. In particular, dependent Claim 3 in Chen recites that the first spin-on glass layer is dispensed for 6 seconds and dried for 15 seconds at “said spin speed” (600-800 rpms in independent Claim 1). Claim 4 is dependent on Claim 3 and recites that the first spin-on glass has a thickness of 2000-4000 Angstroms. Dependent Claim 5 recites that the second spin-on layer is dispensed for 6 seconds and then dried at zero spin speed. Claim 6 is dependent on Claim 5 and recites that the second spin-on glass layer has a thickness of 2000 to 2500 Angstroms. Hence, Chen does not teach or suggest that the second layer 42 is thicker than the first layer 40, and Claims 3-6 are clearly *contrary* to such an interpretation of Chen. These teachings in the claims in Chen are entirely different from the Examiner’s proposed interpretation of Chen. The Examiner provides no good answer for this alleged contradiction. This is clear error by the Examiner.

As explained above, it is well established law that a reference must be considered in its entirety and that one cannot pick and choose isolated disclosures, contrary to the remaining teachings in the reference, to deprecate the claimed invention. See *In re Fine*, 837 F.2d at 1074, 5 USPQ2d at 1600. Further, one cannot use the claims themselves as the blueprint for picking and choosing isolated disclosures in the references to allegedly arrive at the claimed invention. In this case, as shown above, clear teachings in Chen, which are contrary to the Examiner's position, have not been addressed and appear to have been disregarded by the Examiner, in favor of those teachings the Examiner chose based on the claimed invention. This is a clear example of improper hindsight reconstruction.

Further, in support of his position in the Response section, the Examiner cites (at paragraph 5) Col. 6, lines 22-23 in Chen. This section in Chen shows that the first spin-on glass layer is dispensed and dried at a "lower and constant spin speed." This is clearly inconsistent with the Examiner's position in point 3 of the Response to Arguments that the first coating 40 is spun at a higher speed during drying. The Examiner provides no explanation for this contradiction. The only explanation can be that Chen is unreliable and does not teach the thickness of the first layer.

Therefore, the reliance on Chen in the only rejection in the Final Rejection is clearly in error as the Examiner's position is contrary to the teachings in Chen. Hence, the Examiner has not shown a key claimed element of the present application, that the second leveling film is thicker than the first leveling film. As a result, a prima facie case of obviousness has not been established. Further, for the reasons explained above, the rejection is improper hindsight reconstruction, and any case of obviousness by the Examiner has clearly been rebutted.

Accordingly, it is respectfully requested that the rejection be reversed, and the application

allowed.

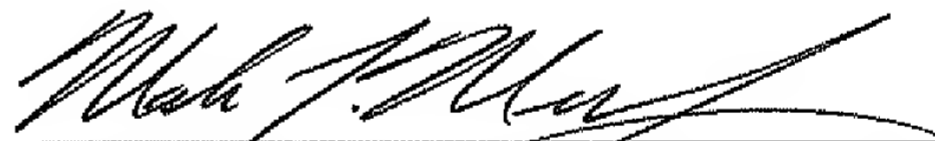
**C. CONCLUSION**

For at least the reasons stated above, Appellant earnestly and respectfully submits that a prima facie case of obviousness has not been established, that any case of obviousness by the Examiner has clearly been rebutted, and that the cited references do not render obvious the claims of the present application and do not show or suggest at least one claimed feature of the claims of the present application. Nor would anything in the prior art or skill of one of ordinary skill in the art suggest improvements by modifying Chen or the other references to arrive at the claimed invention.

Hence, the rejection of the claims should be reversed, and the claims allowed.

Accordingly, Appellant requests that this Appeal be sustained in all respects, and that all rejections in the Final Rejection and Advisory Action be reversed.

Respectfully submitted,



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### **viii. CLAIMS APPENDIX**

In accordance with 37 CFR 41.37(c)(1)(viii), the text of the claims on appeal is as follows:

1. A method of fabricating a display device comprising the steps of:  
  
forming a semiconductor film over a substrate;  
  
forming an interlayer insulating film over the semiconductor film;  
  
forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;  
  
forming a silicon nitride film directly formed on the wiring;  
  
forming a first leveling film on the silicon nitride film; forming a second leveling film structure on said first leveling film, wherein said second leveling film is thicker than said first leveling film; and  
  
forming a pixel electrode over the second leveling film connecting to the wiring through a second hole formed in the silicon nitride film and the first and second leveling films.
  
2. A method of fabricating a display device comprising the steps of:  
  
forming a semiconductor film over a substrate;  
  
forming an interlayer insulating film over the semiconductor film;  
  
forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;  
  
forming a silicon nitride film covering a surface of the wiring;

forming a first leveling film on the silicon nitride film;

forming a second leveling film on said first leveling film, wherein said second leveling film is thicker than said first leveling film; and

forming a pixel electrode over the second leveling film connecting to the wiring through a second hole formed in the silicon nitride film and the first and second leveling films.

3. A method of fabricating a display device comprising the steps of:

forming a semiconductor film over a substrate;

forming an interlayer insulating film over the semiconductor film;

forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;

forming a silicon nitride film deposited on the wiring;

forming a first leveling film on the silicon nitride film;

forming a second leveling film on said first leveling film, wherein said second leveling film is thicker than said first leveling film; and

forming a pixel electrode over the second leveling film connecting to the wiring through a second hole formed in the silicon nitride film and the first and second leveling films.

4. A method of fabricating a display device comprising the steps of:

forming a semiconductor film over a substrate;

forming an interlayer insulating film over the semiconductor film;

forming a wiring connecting to the semiconductor film through a first hole in the interlayer

insulating film on the interlayer insulating film;

forming a silicon nitride oxide film directly formed on the wiring;

forming a first leveling film on the silicon nitride oxide film;

forming a second leveling film on said first leveling film, wherein said second leveling film is thicker than said first leveling film; and

forming a pixel electrode over the second leveling film connecting to the wiring through a second hole formed in the silicon nitride oxide film and the first and second leveling films.

5. A method of fabricating a display device comprising the steps of:

forming a semiconductor film over a substrate;

forming an interlayer insulating film over the semiconductor film;

forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;

forming a silicon nitride oxide film covering a surface of the wiring;

forming a first leveling film on the silicon nitride oxide film;

forming a second leveling film on said first leveling film, wherein said second leveling film is thicker than said first leveling film; and

forming a pixel electrode over the second leveling film connecting to the wiring through a second hole formed in the silicon nitride oxide film and the first and second leveling films.

6. A method of fabricating a display device comprising the steps of:

forming a semiconductor film over a substrate;

forming an interlayer insulating film over the semiconductor film;  
forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;  
forming a silicon nitride oxide film deposited on the wiring;  
forming a first leveling film on the silicon nitride oxide film;  
forming a second leveling film on said first leveling film, wherein said second leveling film is thicker than said first leveling film; and  
forming a pixel electrode over the second leveling film connecting to the wiring through a second hole formed in the silicon nitride oxide film and the first and second leveling films.

7. A method of fabricating a display device comprising the steps of:  
forming a semiconductor film over a substrate;  
forming an interlayer insulating film over the semiconductor film;  
forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;  
forming a silicon nitride film directly formed on the wiring;  
forming a first leveling film on the silicon nitride film;  
forming a second leveling film on said first leveling film, wherein said second leveling film is thicker than said first leveling film;  
forming a pixel electrode connecting the wiring through a second hole in the silicon nitride film and the first and second leveling films over the second leveling film; and  
forming an electro luminescence layer over the pixel electrode.

8. A method of fabricating a display device comprising the steps of:

- forming a semiconductor film over a substrate;
- forming an interlayer insulating film over the semiconductor film;
- forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;
- forming a silicon nitride oxide film directly formed on the wiring;
- forming a first leveling film on the silicon nitride oxide film;
- forming a second leveling film on said first leveling film, wherein said second leveling film is thicker than said first leveling film;
- forming a pixel electrode connecting the wiring through a second hole in the silicon nitride oxide film and the first and second leveling films over the second leveling film;
- forming an electro luminescence layer over the pixel electrode; and
- forming a cathode made of a conductive film having a light-shielding property.

9. A method of fabricating a display device comprising the steps of:

- forming a semiconductor film over a substrate;
- forming an interlayer insulating film over the semiconductor film;
- forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;
- forming a silicon nitride oxide film directly formed on the wiring;
- forming a first leveling film on the silicon nitride oxide film;
- forming a second leveling film on said first leveling film, wherein said second leveling film

is thicker than said first leveling film;

forming a pixel electrode connecting the wiring through a second hole in the silicon nitride oxide film and the first and second leveling films over the second leveling film; and

forming an electro luminescence layer over the pixel electrode.

10. A method of fabricating a semiconductor device comprising the steps of:

forming a semiconductor film over a substrate;

forming an interlayer insulating film over the semiconductor film;

forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;

forming a second insulating film comprising a material selected from the group consisting of silicon nitride and silicon nitride oxide directly formed on the wiring;

forming a first leveling film formed by a spin coating method on the second insulating film;  
and

forming a second leveling film by a spin coating method on said first leveling film, wherein said second leveling film is thicker than said first leveling film.

12. The method according to claim 1, wherein the display device is used in one selected from the group consisting of a portable phone, a video camera, a computer, and a projector.

14. The method according to claim 2, wherein the display device is used in one selected from the group consisting of a portable phone, a video camera, a computer, and a projector.

16. The method according to claim 3, wherein the display device is used in one selected from the group consisting of a portable phone, a video camera, a computer, and a projector.

18. The method according to claim 4, wherein the display device is used in one selected from the group consisting of a portable phone, a video camera, a computer, and a projector.

20. The method according to claim 5, wherein the display device is used in one selected from the group consisting of a portable phone, a video camera, a computer, and a projector.

22. The method according to claim 6, wherein the display device is used in one selected from the group consisting of a portable phone, a video camera, a computer, and a projector.

24. The method according to claim 7, wherein the display device is used in one selected from the group consisting of a portable phone, a video camera, a computer, and a projector.

26. The method according to claim 8, wherein the display device is used in one selected from the group consisting of a portable phone, a video camera, a computer, and a projector.

28. The method according to claim 9, wherein the display device is used in one selected from the group consisting of a portable phone, a video camera, a computer, and a projector.

31. A method of fabricating a semiconductor device comprising the steps of:

forming a semiconductor film over a substrate;

forming an interlayer insulating film over the semiconductor film;

forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;

forming a second insulating film comprising a material selected from the group consisting of silicon nitride and silicon nitride oxide covering a surface of the wiring;

forming a first leveling film by a spin coating method on the second insulating film; and

forming a second leveling film by a spin coating method on said first leveling film, wherein said second leveling film is thicker than said first leveling film.

33. A method of fabricating a semiconductor device comprising the steps of:

forming a semiconductor film over a substrate;

forming an interlayer insulating film over the semiconductor film;

forming a wiring connecting to the semiconductor film through a first hole in the interlayer insulating film on the interlayer insulating film;

forming a second insulating film comprising a material selected from the group consisting of silicon nitride and silicon nitride oxide deposited on the wiring;

forming a first leveling film by a spin coating method on the second insulating film; and

forming a second leveling film by a spin coating method on said first leveling film, wherein said second leveling film is thicker than said first leveling film.

35. The method according to claim 1, wherein the wiring is formed by a sputtering method.

36. The method according to claim 1, wherein the wiring comprises aluminum.
37. The method according to claim 1, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.
38. The method according to claim 1, wherein the display device is a liquid crystal display device or an electro luminescence display device.
39. The method according to claim 1, wherein the silicon nitride film has a thickness of 50 to 500nm.
40. The method according to claim 1, wherein the silicon nitride film has a thickness of 200 to 300nm.
41. The method according to claim 1, wherein the first leveling film has a thickness of 0.1  $\mu$  m to 1.5  $\mu$  m.
43. The method according to claim 1, wherein the pixel electrode is made of a conductive oxide film.
44. The method according to claim 2, wherein the wiring is formed by a sputtering method.

45. The method according to claim 2, wherein the wiring comprises aluminum.
46. The method according to claim 2, wherein the wiring is a three-layered laminate film containing a first titanium, an aluminum film and a second titanium.
47. The method according to claim 2, wherein the display device is a liquid crystal display device or an electro luminescence display device.
48. The method according to claim 2, wherein the silicon nitride film has a thickness of 50 to 500nm.
49. The method according to claim 2, wherein the silicon nitride film has a thickness of 200 to 300nm.
50. The method according to claim 2, wherein the first leveling film has a thickness of 0.1  $\mu\text{m}$  to 1.5  $\mu\text{m}$ .
52. The method according to claim 2, wherein the pixel electrode is made of a conductive oxide film.
53. The method according to claim 3, wherein the wiring is formed by a sputtering method.

54. The method according to claim 3, wherein the wiring comprises aluminum.
55. The method according to claim 3, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.
56. The method according to claim 3, wherein the display device is a liquid crystal display device or an electro luminescence display device.
57. The method according to claim 3, wherein the silicon nitride film has a thickness of 50 to 500nm.
58. The method according to claim 3, wherein the silicon nitride film has a thickness of 200 to 300nm.
59. The method according to claim 3, wherein the first leveling film has a thickness of 0.1  $\mu$  m to 1.5  $\mu$  m.
61. The method according to claim 3, wherein the pixel electrode is made of a conductive oxide film.
62. The method according to claim 4, wherein the wiring is formed by a sputtering method.

63. The method according to claim 4, wherein the wiring comprises aluminum.

64. The method according to claim 4, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.

65. The method according to claim 4, wherein the display device is a liquid crystal display device or an electro luminescence display device.

66. The method according to claim 4, wherein the silicon nitride oxide film has a thickness of 50 to 500nm.

67. The method according to claim 4, wherein the silicon nitride oxide film has a thickness of 200 to 300nm.

68. The method according to claim 4, wherein the first leveling film has a thickness of 0.1  $\mu\text{m}$  to 1.5  $\mu\text{m}$ .

70. The method according to claim 4, wherein the pixel electrode is made of a conductive oxide film.

71. The method according to claim 5, wherein the wiring is formed by a sputtering method.

72. The method according to claim 5, wherein the wiring comprises aluminum.
73. The method according to claim 5, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.
74. The method according to claim 5, wherein the display device is a liquid crystal display device or an electro luminescence display device.
75. The method according to claim 5, wherein the silicon nitride oxide film has a thickness of 50 to 500nm.
76. The method according to claim 5, wherein the silicon nitride oxide film has a thickness of 200 to 300nm.
77. The method according to claim 5, wherein the first leveling film has a thickness of 0.1  $\mu$  m to 1.5  $\mu$  m.
79. The method according to claim 5, wherein the pixel electrode is made of a conductive oxide film.
80. The method according to claim 6, wherein the wiring is formed by a sputtering method.

81. The method according to claim 6, wherein the wiring comprises aluminum.
82. The method according to claim 6, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.
83. The method according to claim 6, wherein the display device is a liquid crystal display device or an electro luminescence display device.
84. The method according to claim 6, wherein the silicon nitride oxide film has a thickness of 50 to 500nm.
85. The method according to claim 6, wherein the silicon nitride oxide film has a thickness of 200 to 300nm.
86. The method according to claim 6, wherein the first leveling film has a thickness of 0.1  $\mu$  m to 1.5  $\mu$  m.
88. The method according to claim 6, wherein the pixel electrode is made of a conductive oxide film.
89. The method according to claim 7, wherein the wiring is formed by a sputtering method.

90. The method according to claim 7, wherein the wiring comprises aluminum.
91. The method according to claim 7, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.
93. The method according to claim 7, wherein the silicon nitride film has a thickness of 50 to 500nm.
94. The method according to claim 7, wherein the silicon nitride film has a thickness of 200 to 300nm.
95. The method according to claim 7, wherein the first leveling film has a thickness of 0.1  $\mu\text{m}$  to 1.5  $\mu\text{m}$ .
97. The method according to claim 7, wherein the second hole is formed by a dry etching method.
98. The method according to claim 7, wherein the pixel electrode is made of a conductive oxide film.
99. The method according to claim 8, wherein the wiring is formed by a sputtering method.

100. The method according to claim 8, wherein the wiring comprises aluminum.

101. The method according to claim 8, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.

103. The method according to claim 8, wherein the silicon nitride oxide film has a thickness of 50 to 500nm.

104. The method according to claim 8, wherein the silicon nitride oxide film has a thickness of 200 to 300nm.

105. The method according to claim 8, wherein the first leveling film has a thickness of 0.1  $\mu\text{m}$  to 1.5  $\mu\text{m}$ .

107. The method according to claim 8, wherein the second hole is formed by a dry etching method.

108. The method according to claim 8, wherein the pixel electrode is made of a conductive oxide film.

109. The method according to claim 9, wherein the wiring is formed by a sputtering method.

110. The method according to claim 9, wherein the wiring comprises aluminum.
111. The method according to claim 9, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.
113. The method according to claim 9, wherein the silicon nitride oxide film has a thickness of 50 to 500nm.
114. The method according to claim 9, wherein the silicon nitride oxide film has a thickness of 200 to 300nm.
115. The method according to claim 9, wherein the first leveling film has a thickness of 0.1  $\mu\text{m}$  to 1.5  $\mu\text{m}$ .
117. The method according to claim 9, wherein the second hole is formed by a dry etching method.
118. The method according to claim 9, wherein the pixel electrode is made of a conductive oxide film.
119. The method according to claim 10, wherein the wiring is formed by a sputtering

method.

120. The method according to claim 10, wherein the wiring comprises aluminum.

121. The method according to claim 10, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.

123. The method according to claim 10, wherein the second insulating film has a thickness of 50 to 500nm.

124. The method according to claim 10, wherein the second insulating film has a thickness of 200 to 300nm.

125. The method according to claim 10, wherein the first leveling film has a thickness of 0.1  $\mu\text{m}$  to 1.5  $\mu\text{m}$ .

127. The method according to claim 10, wherein each of the first and second leveling films comprises an inorganic spin on glass material.

129. The method according to claim 31, wherein the wiring is formed by a sputtering method.

130. The method according to claim 31, wherein the wiring comprises aluminum.

131. The method according to claim 31, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.

133. The method according to claim 31, wherein the second insulating film has a thickness of 50 to 500nm.

134. The method according to claim 31, wherein the second insulating film has a thickness of 200 to 300nm.

135. The method according to claim 31, wherein the first leveling film has a thickness of 0.1  $\mu\text{m}$  to 1.5  $\mu\text{m}$ .

137. The method according to claim 31, wherein each of the first and second leveling films comprises an inorganic spin on glass material.

139. The method according to claim 33, wherein the wiring is formed by a sputtering method.

140. The method according to claim 33, wherein the wiring comprises aluminum.

141. The method according to claim 33, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.

143. The method according to claim 33, wherein the second insulating film has a thickness of 50 to 500nm.

144. The method according to claim 33, wherein the second insulating film has a thickness of 200 to 300nm.

145. The method according to claim 33, wherein the first leveling film has a thickness of 0.1  $\mu\text{m}$  to 1.5  $\mu\text{m}$ .

147. The method according to claim 33, wherein each of the first and second leveling films comprises an inorganic spin on glass material.

149. A method of fabricating a semiconductor device comprising the steps of:  
forming a wiring on a first insulating film;  
forming a second insulating film comprising silicon nitride oxide over said wiring;  
forming a first leveling film by a spin coating method on the second insulating film; and  
forming a second leveling film on the first leveling film by a spin coating method, wherein said second leveling film is thicker than said first leveling film.

150. The method according to claim 149, wherein the wiring is formed by a sputtering method.

151. The method according to claim 149, wherein the wiring comprises aluminum.

152. The method according to claim 149, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.

154. The method according to claim 149, wherein the second insulating film has a thickness of 50 to 500nm.

155. The method according to claim 149, wherein the second insulating film has a thickness of 200 to 300nm.

156. The method according to claim 149, wherein the first leveling film has a thickness of 0.1  $\mu$  m to 1.5  $\mu$  m.

158. The method according to claim 149, wherein each of the first and second leveling films comprises an inorganic spin on glass material.

161. A method of fabricating a semiconductor device comprising the steps of:

forming an insulating film over a wiring;  
forming a first leveling film by a spin coating method on the insulating film; and  
forming a second leveling film on the first leveling film by a spin coating method, wherein  
said second leveling film is thicker than said first leveling film.

162. The method according to claim 161, wherein the wiring is formed by a sputtering method.

163. The method according to claim 161, wherein the wiring comprises aluminum.

164. The method according to claim 161, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.

166. The method according to claim 161, wherein the second insulating film has a thickness of 50 to 500nm.

167. The method according to claim 161, wherein the second insulating film has a thickness of 200 to 300nm.

168. The method according to claim 161, wherein the first leveling film has a thickness of 0.1  $\mu$  m to 1.5  $\mu$  m.

170. The method according to claim 161, wherein each of the first and second leveling films comprises an inorganic spin on glass material.

173. A method of fabricating a semiconductor device comprising the steps of:  
forming a wiring on a first insulating film;  
forming a second insulating film comprising silicon nitride over said wiring film;  
forming a first leveling film by a spin coating method on the second insulating film; and  
forming a second leveling film on said first leveling film by spin coating, wherein said second leveling film is thicker than said first leveling film.

174. The method according to claim 173, wherein the wiring is formed by a sputtering method.

175. The method according to claim 173, wherein the wiring comprises aluminum.

176. The method according to claim 173, wherein the wiring is a three-layered laminate film containing a first titanium film, an aluminum film and a second titanium film.

178. The method according to claim 173, wherein the second insulating film has a thickness of 50 to 500nm.

179. The method according to claim 173, wherein the second insulating film has a thickness

of 200 to 300nm.

180. The method according to claim 173, wherein the first leveling film has a thickness of 0.1  $\mu$  m to 1.5  $\mu$  m.

182. The method according to claim 173, wherein each of the first and second leveling films comprises an inorganic spin on glass material.

185. The method according to claim 10 wherein each of said first and second leveling films comprises a resin.

186. The method according to claim 10 wherein each of said first and second leveling films comprises a material selected from the group consisting of phosphosilicate glass, borosilicate glass and borophosphosilicate glass.

187. The method according to claim 31 wherein each of said first and second leveling films comprises a resin.

188. The method according to claim 31 wherein each of said first and second leveling films comprises a material selected from the group consisting of phosphosilicate glass, borosilicate glass and borophosphosilicate glass.

189. The method according to claim 33 wherein each of said first and second leveling films comprises a resin.

190. The method according to claim 33 wherein each of said first and second leveling films comprises a material selected from the group consisting of phosphosilicate glass, borosilicate glass and borophosphosilicate glass.

191. The method according to claim 149 wherein each of said first and second leveling films comprises a resin.

192. The method according to claim 149 wherein each of said first and second leveling films comprises a material selected from the group consisting of phosphosilicate glass, borosilicate glass and borophosphosilicate glass.

193. The method according to claim 161 wherein each of said first and second leveling films comprises a resin.

194. The method according to claim 161 wherein each of said first and second leveling films comprises a material selected from the group consisting of phosphosilicate glass, borosilicate glass and borophosphosilicate glass.

195. The method according to claim 173 wherein each of said first and second leveling films

comprises a resin.

196. The method according to claim 173 wherein each of said first and second leveling films comprises a material selected from the group consisting of phosphosilicate glass, borosilicate glass and borophosphosilicate glass.

197. The method according to claim 1 wherein said first and second leveling films contain a siloxane structure.

198. The method according to claim 2 wherein said first and second leveling films contain a siloxane structure.

199. The method according to claim 3 wherein said first and second leveling films contain a siloxane structure.

200. The method according to claim 4 wherein said first and second leveling films contain a siloxane structure.

201. The method according to claim 5 wherein said first and second leveling films contain a siloxane structure.

202. The method according to claim 6 wherein said first and second leveling films contain a siloxane structure.

203. The method according to claim 7 wherein said first and second leveling films contain a siloxane structure.

204. The method according to claim 8 wherein said first and second leveling films contain a siloxane structure.

205. The method according to claim 9 wherein said first and second leveling films contain a siloxane structure.

### **ix. EVIDENCE APPENDIX**

Dietrich Meyerhofer, "Characteristics of resist films produced by spinning," J. Appl. Phys. 49(7), July 1978, p. 3993-3997. Filed with the Response (M) to the Office Action and the IDS filed August 16, 2006. Entered by Examiner in the Final Rejection of October 20, 2006 and of record in this application.

Honeywell, Electronic Materials, Accuglass T-11, Product Bulletin, Thin Films-Dielectrics (2002). Filed with Response (M) of Office Action and the IDS filed August 16, 2006. Entered by Examiner in the Final Rejection of October 20, 2006 and of record in this application.

Trademark Materials for Accuglass. Filed with Response (M) to Office Action filed August 16, 2006. Entered by Examiner in the Final Rejection of October 20, 2006 and of record in this application. The trademark for Accuglass is currently owned by Honeywell. Honeywell received this trademark from AlliedSignal as the result of a merger.

**x. RELATED PROCEEDINGS APPENDIX**

Appellant has filed an appeal in related application 10/951,065 on August 23, 2007. Appellants' brief for that appeal was filed on the same day (September 19, 2007) as this brief. No decision has yet been issued in that proceeding.

# Characteristics of resist films produced by spinning

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A model is presented for the description of thin films prepared from solution by spinning. Using only the centrifugal force, linear shear forces, and uniform evaporation of the solvent, the thickness of the film and the time of drying can be calculated as functions of the various processing parameters. The model is compared with experimental results obtained on positive photoresists and excellent agreement is obtained. When adequate care is taken, the liquid forms a level surface during spinning, and the film thickness becomes uniform and independent of the size of the substrate. The film thickness  $h$  shows the following dependence on spin speed  $f$ , initial viscosity  $\nu_0$ , and evaporation rate  $e$ :  $h \propto f^{-2/3} \nu_0^{1/3} e^{1/3}$ , and  $e$  is proportional to  $f^{1/2}$ .

PACS numbers: 68.15.+e, 62.10.+s, 47.15.-x, 81.15.Lm

## INTRODUCTION

Production of thin organic films, such as photoresist, by centrifugal spinning from solution on rotating disks is a simple technique which is widely used. A thick layer of solution is applied to the disk. During rotation, the solution flows radially outward. As the liquid layer thins, evaporation of the solvent increases the concentration of the solids causing increased viscosity and formation of the solid film. This technique can lead to very uniform films of well-controlled thickness. Despite its wide usage, no complete description of the process appears in the literature explaining the uniformity of the films and the dependence of the process on material parameters. This report attempts such a description and compares it with experimental results on films of positive-working photoresists.

The first description of the flow of a viscous liquid on a rotating disk was given by Emslie, Bonner, and Peck.<sup>1</sup> They showed that, for a Newtonian fluid (linear relationship between shear stress and shear rate), the solution of the hydrodynamic equations leads asymptotically to a layer of uniform thickness, independent of the liquid profile at the start of the rotation. The thickness, of course, decreases continuously with time as material is spun away. Acrivos, Shah, and Petersen<sup>2</sup> extended this calculation to non-Newtonian liquids and showed that the film no longer approached a uniform-thickness condition. The effect only becomes significant for large deviations from linearity. Neither of these papers, nor any others that the author is aware of, examines the real situation in which evaporation of a solvent is taken into account so that, at the end of the procedure, a solid film remains with a predetermined thickness profile.<sup>3</sup>

Because of the widespread use of the spinning technique, numerous measurements of profile and film thickness have been reported. They are well represented by the results of Damon on Kodak photoresists.<sup>4</sup> He observed that the following equation described the dependence of the final film thickness  $h$  on spinner rotation rate  $f$  and on initial solids concentration  $c_0$  for the various resist materials he investigated:

$$h = k c_0^2 / f^{1/2}. \quad (1)$$

The constant  $k$ , which must be a function of the polymer-solvent system, was also found to depend on the equipment used.

## MODEL OF THE SPINNING PROCESS

In order to calculate the hydrodynamics of the spin-coating process, we first assume as a starting point that a layer of polymer solution of uniform thickness  $h_0$  is applied on the horizontal surface of a circular substrate. At time 0, the substrate is spun at a rotation rate  $f$ . If the solution has approximately Newtonian character, then Emslie *et al.*<sup>1</sup> have shown that the hydrodynamics are governed by the following equations:

Force balance:

$$-\eta \frac{\partial^2 v}{\partial z^2} = \rho \omega^2 r; \quad (2)$$

continuity:

$$\frac{\partial h}{\partial t} = -\frac{1}{r} \frac{\partial(rq)}{\partial r}. \quad (3)$$

Here the  $z$  axis is the rotation axis,  $r$  is the radial direction, and cylindrical symmetry is assumed. Thus the velocity  $v(z)$  is the  $r$  direction. Gravitational and Coriolis forces are neglected.  $\eta$  is the viscosity,  $\rho$  is the density,  $\omega = 2\pi f$ , and we define the kinematic viscosity  $\nu = \eta/\rho$ . The total radial flow per unit circumference is given by

$$q = \omega^2 r h^3 / 3\nu. \quad (4)$$

The solution of these equations when there is no evaporation (no change in  $\nu$ ) is that the profile remains uniform and that  $h$  decreases as

$$h = h_0 [1 + (4\omega^2/3\nu) h_0^2 t]^{-1/2}. \quad (5)$$

In order to produce a solid film, the solvent must evaporate. At the start of the spinning, the concentration of the solute is uniform. The solvent evaporates uniformly over the entire surface area causing the solids concentration  $c$  to increase. As  $h$  is independent of  $r$  [Eq. (5)],  $c$  will also be independent of  $r$  (while there will be some change of  $c$  with  $z$ , this can be neglected in these thin films). In order to simplify the discussion, we assume that both solute and solvent

have density unity, and that the volume of the solution is equal to the volume of the solvent ( $L$ ) plus the volume of the solids ( $S$ ) that would exist after the evaporation of all the solvent. While real solutions do not obey this assumption, the difference is small over the concentration ranges used and does not affect the final results. We define  $L$  and  $S$  per unit area and thus obtain

$$c(t) = S/(S + L) \quad (6)$$

and

$$h = S + L.$$

The change in concentration affects the hydrodynamics through the dependence of viscosity on concentration. Because there is no dependence on  $r$ , the film thickness will continue to reduce uniformly, but the rate is different from that given by Eq. (5). We write the rate of change of  $S$  and  $L$  due to outflow and evaporation (at a rate  $e$ ):

$$\frac{dS}{dt} = -c \frac{1}{r} \frac{\partial(rq)}{\partial r} = -c \frac{2\omega^2 h^3}{3\nu}, \quad (7)$$

$$\frac{dL}{dt} = -(1 - c) \frac{2\omega^2 h^3}{3\nu} - e. \quad (8)$$

The equations are expressed in terms of rate of change of volume per unit area (m/s). The two coupled equations can be integrated from the initial thickness and concentration values to the point where  $L = 0$ , i.e., only the solid film remains. At that point, the final film thickness  $h_f = S_f$ .

This calculation was performed numerically in order to determine the dependence of the final thickness and the time to drying on the various parameters. The viscosity of many of these solutions has been reported to be a power-law function of the concentration, and, for the purposes of calculation, we use the relationship

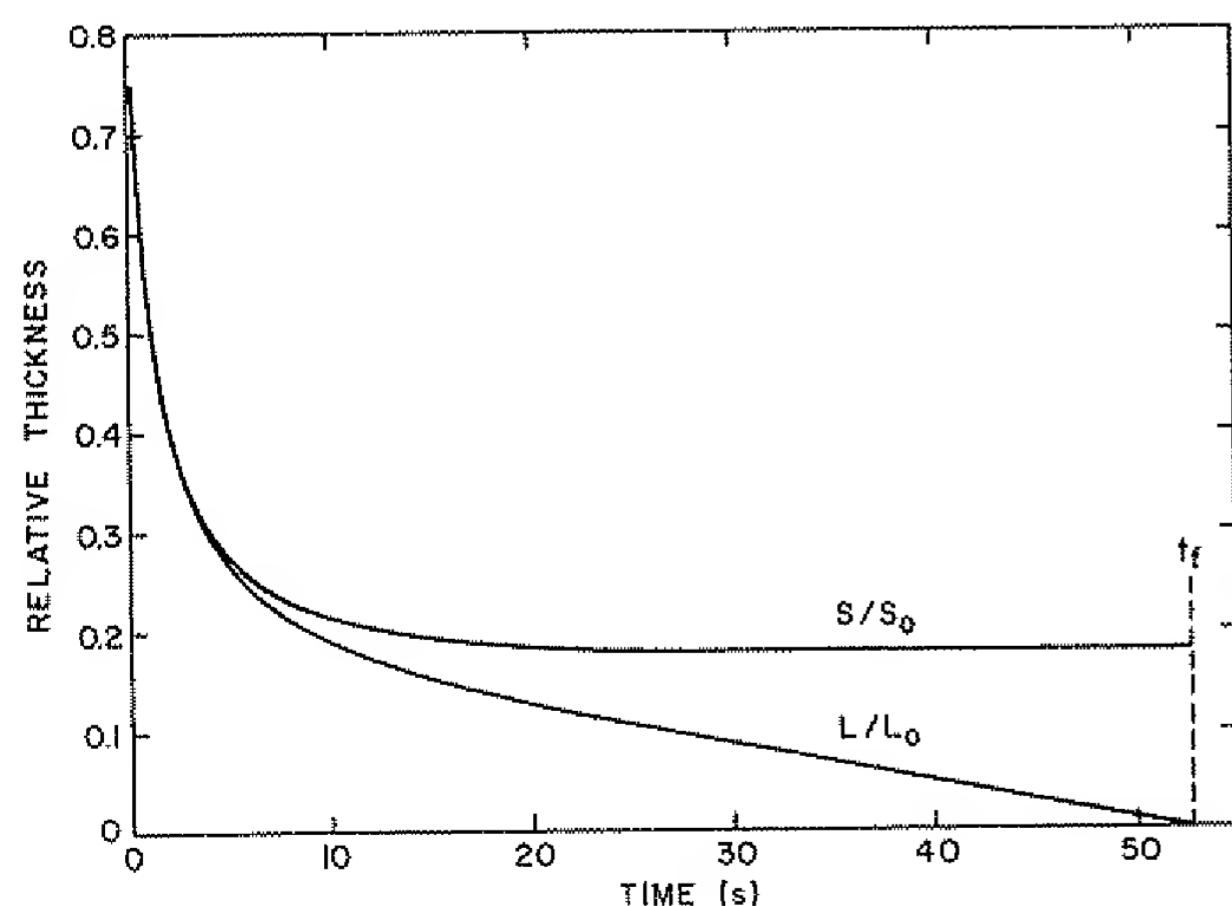


FIG. 1. Calculated time dependence during spinning of the volume of solids ( $S$ ) and solvent ( $L$ ) per unit area normalized to the initial values. The parameter values used are initial thickness  $h_0 = 30 \mu\text{m}$ , initial concentration  $c_0 = 0.10$ , spin speed  $= 4500 \text{ rpm}$ , viscosity  $\nu = (1 \times 10^{-3} + c^4) \text{ m}^2/\text{s}$ , initial value  $\nu_0 = 1 \times 10^{-4} \text{ m}^2/\text{s}$ , evaporation rate  $e = 1 \times 10^{-7} \text{ m/s}$ .

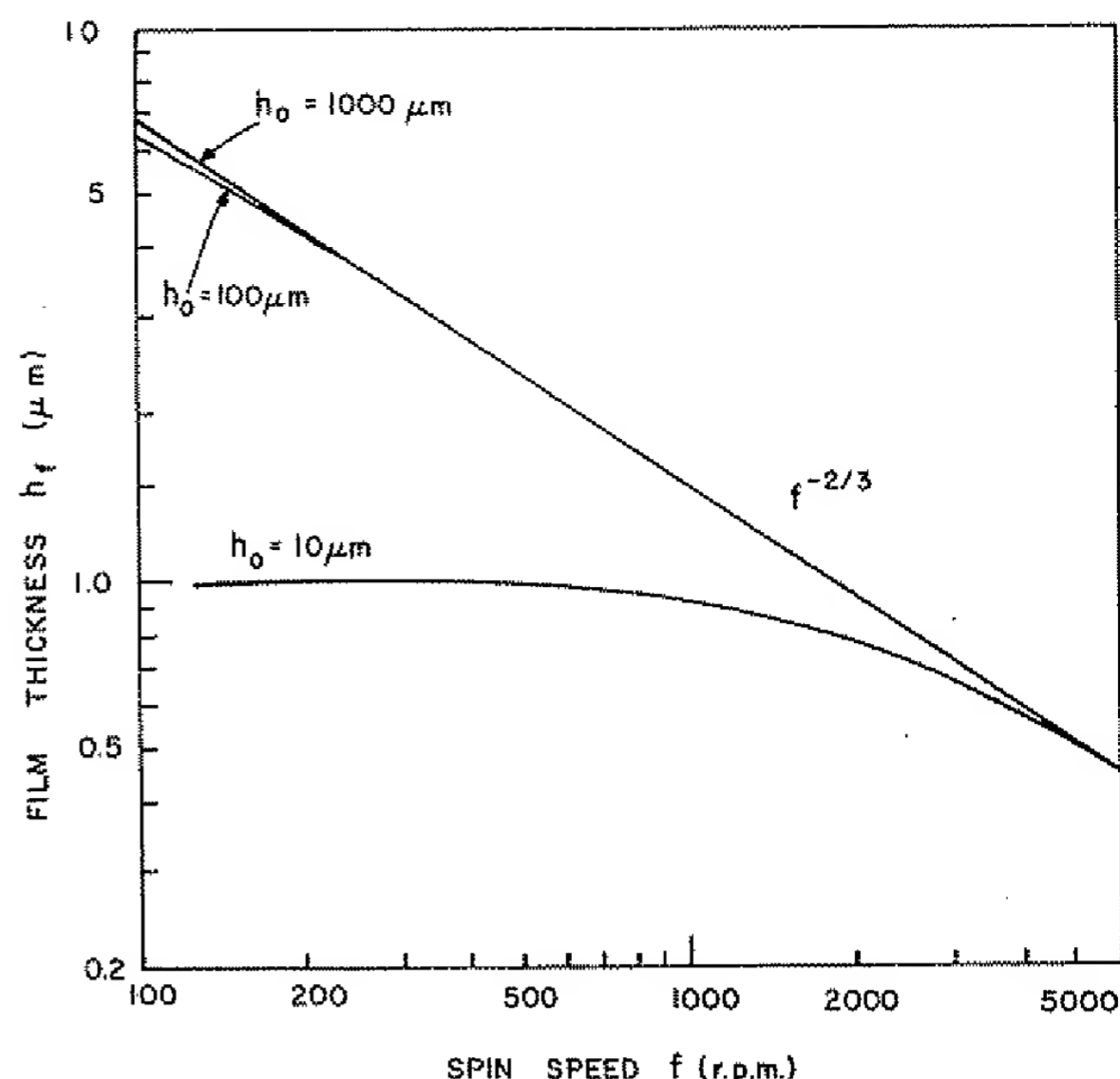


FIG. 2. Calculated film thickness as function of spin speed. The parameter values are the same as in Fig. 1, except as indicated.

$$\nu = \nu_{\text{solvent}} + \nu_{\text{solids}} c^\gamma. \quad (9)$$

The exponent  $\gamma$  typically has values around 2.5 for photoresist solutions.<sup>1</sup> The value of  $e$  is taken to be constant with time, because we are not able to measure or calculate its actual value. However, allowing  $e$  to vary during the integration produces only small changes in  $h_f$ .

The result of a typical integration is shown in Fig. 1. Both volume of solvent and volume of solids relative to their initial values are plotted as a function of time. The values of the parameters used are indicated in Fig. 1. The curves show that, at the start, the outflow dominates and the concentration does not change much. When  $h$  has dropped to about  $\frac{1}{3}h_0$ , evaporation takes over and  $S$  rapidly reaches its final value. Flow has ceased completely due to the high viscosity and the reduced liquid thickness. Only evaporation continues.

Figure 2 shows the calculated final film thickness as the spin speed is varied. The values of the parameters used are listed in Fig. 2. Three different values of initial thickness of the solution are shown. If  $h_0 = 10 \mu\text{m}$ , then, at the lower speeds, there is no outflow at all and only evaporation down to a thickness of  $S_f = ch_0$ . On the other hand, it is shown that, at high enough speeds, there is no dependence on the initial height of the liquid. There, the thickness is proportional to the  $-\frac{2}{3}$  power of the speed. Inspection of Fig. 2 shows that this relationship applies for  $S_0 = c_0 h_0 \gtrsim 2h_f$ .

While Eqs. (7)–(9) cannot be solved analytically, we can use the results of Fig. 1 and 2 to derive an approximate value of  $h_f$  in the range  $S_0 > 2h_f$ . We assume that, at the outset, evaporation is negligible and that this condition applies until the liquid film thins to a value  $h_{1/2}$  at which the evaporation and outflow contributions in Eq. (8) are equal:

$$(1 - c)2\omega^2 h^3 / 3\nu = e, \quad (10)$$

where  $c = c_0$  and  $\nu = \nu_0$ . We further assume that, from this point on, the outflow is negligible compared to the evaporation, so that

$$h_f = S_f = c_0 h_{1/2} = \left(\frac{3}{2}\right)^{1/3} c_0 (1 - c_0)^{-1/3} \omega^{-2/3} \nu_0^{1/3} e^{1/3} \quad (11)$$

for  $S_0 \gg 2h_f$ . This relationship shows the same dependence on spin speed as the exact calculation (Fig. 2), so that we can compare the two quantitatively. Using the values of  $c_0$ ,  $\nu_0$ , and  $e$  given in Fig. 1, Eq. (11) gives  $h_f$  at 4500 rpm to be  $0.42 \mu\text{m}$  compared to the exact value  $0.54 \mu\text{m}$  (Fig. 2). Additional calculations show that in the high- $h_0$ /high- $\omega$  range  $h_f$  depends on  $\nu_0$  and on  $e$  exactly as is given by Eq. (11). Thus, the simple assumptions used provide a remarkably good approximation in this range. One of the reasons for this is that the calculated  $h_f$  does not depend strongly on the exact form and values of Eq. (9). For example, varying  $\gamma$  from 2 to 6 while keeping  $\nu_0$  constant only causes  $h_f$  to vary from  $0.50$  to  $0.60 \mu\text{m}$  in the above case.

## EXPERIMENTAL RESULTS

The predictions of the spinning model were tested on some positive-working photoresists. We used both Shipley AZ-1350 and Mark II', a similar mixture. Various concentrations were prepared by dissolving both starting materials in methyl cellosolve acetate.

In order to justify the approximations of the model, it was necessary to use adequately flat and horizontal substrates and a high acceleration whirler. A Headway Research 1-EC101-R285 spinner was used and carefully leveled. Square glass substrates,  $5 \times 5 \text{ cm}$ , were held flat on a special vacuum chuck of the same size, with vacuum holes only at the four corners (even small vacuum holes distort a 1-mm thick glass slide to the point where small differences in film thickness over the holes can be seen after spinning). The solution was applied to cover the entire substrate with a thickness of at least 1 mm and then the spinner was turned on. Acceleration to full speed

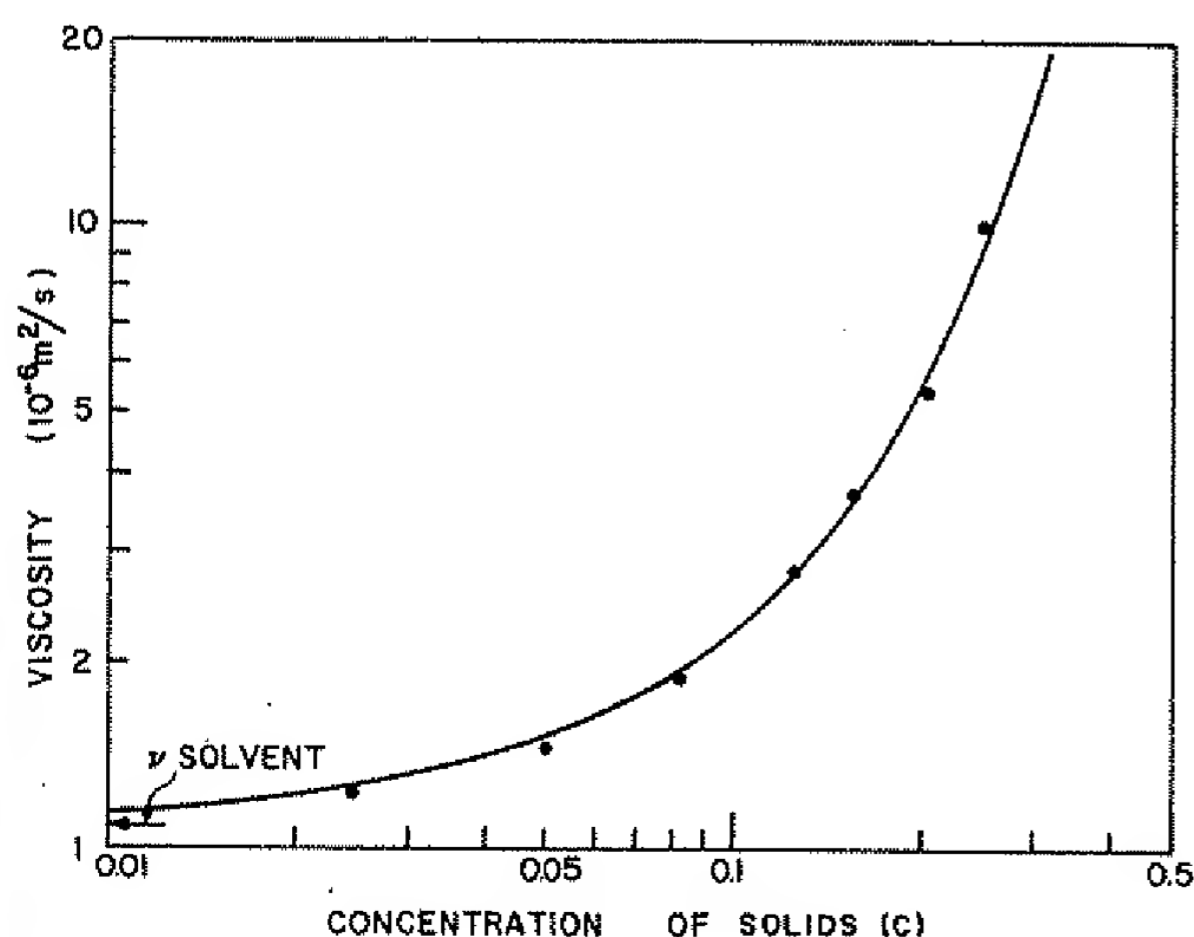


FIG. 3. Viscosity of Mark II' solutions at  $25^\circ\text{C}$  ( $1 \times 10^{-6} \text{ m}^2/\text{s} = 1 \text{ cS}$ ).

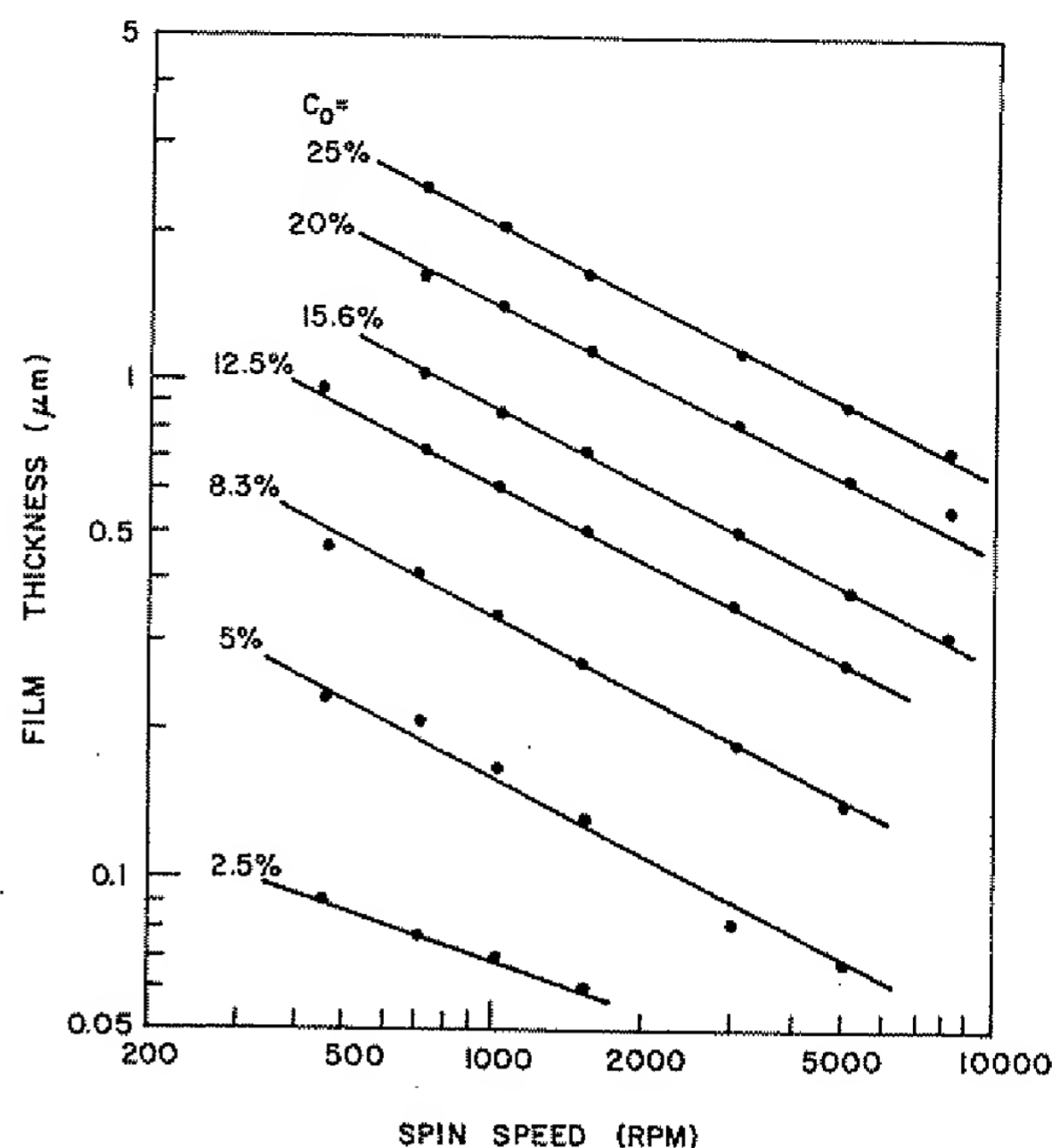


FIG. 4. Measured film thickness as function of spin speed (in rpm) and solute concentration.

takes place in a small fraction of a second, and the speed is accurately controlled by a servomechanism. Spinning was continued until the films were visually dry.

The topography of the surface of the solution was observed visually during spinning. After the first fraction of a second, the surface appeared completely flat and remained so. As the layer thinned out, interference colors were observed to change uniformly through the various orders. This confirms the predictions of the model of Emslie *et al.*<sup>1</sup> The kinds of instabilities in the flow described by Damon<sup>4</sup> ("waves of liquid moving from the center out") can be observed when the acceleration is not rapid enough (of the order of 0.2 s or larger) or when the solution is applied very nonuniformly, and particularly at low spin speeds. The uniformity of our solid films was established by determining the thickness at a number of different points on the film. We measured the reflection spectrum over the visible range and determined the thickness from the interference extrema to a precision of approximately  $\pm 2 \text{ nm}$ .<sup>5</sup> On a typical  $5 \times 5 \text{ cm}$  slide, the central  $2.5 \times 2.5 \text{ cm}$  had a total thickness variation of 5 nm out of 860 nm. We have observed a similar degree of uniformity over much larger areas when spin coating circular substrates as large as 35 cm in diameter.<sup>6</sup> Furthermore, at a given spin speed, the absolute film thickness on the largest substrates was found to be the same as on the  $5 \times 5 \text{ cm}$  squares.

Before measuring the film thickness, we determined the dependence of viscosity on the concentration of solids in the solution,  $c$ . The result for Mark II' resist is shown in Fig. 3. The curve for Shipley AZ-1350 (starting either with 1350J or 1350B) is very similar and slightly steeper at concentrations above 0.20.

The curve is described by Eq. (9) over the range from  $c=0.025$  to  $0.20$ :

$$\nu = (1.18 \times 10^{-6} + 1.0 \times 10^{-4} c^{2.0}) \text{ m}^2/\text{s}. \quad (12)$$

The measured values of Mark II' film thickness as function of spin speed and concentration are shown in Fig. 4. Except for the very dilute solution, all curves follow a  $f^{-0.5}$  dependence over the entire range within experimental error. This is in agreement with Eq. (1)<sup>4</sup> and many other observations on resists. Other measurements<sup>7</sup> have shown that the power law extends down to spin speeds of 100 rpm for Shipley AZ-1350. It does not agree with the  $f^{-2/3}$  dependence calculated (Fig. 2) unless it is assumed that  $e$  depends on spin speed as  $e \propto f^{1/2}$ .

A spin dependence of  $e$  is also supported by the fact that  $e$  depends very strongly on how fast the vapor phase above the liquid is removed. If, e.g., the spinner is enclosed in a housing, the film thickness produced decreases to an extent which indicates a change in  $e$  of a factor of 2–3. We are not able to measure  $e$  independently to determine the dependence on  $f$ . However, the rate of evaporation must be related to the air flow over the spinning disk, a problem that has been solved<sup>8</sup> for the case of an infinitely large disk. There, it was found that the rate of fresh air flowing onto the disk per unit area from above is uniform and proportional to  $f^{1/2}$ . The simplest model suggests that the rate of evaporation is proportional to the rate of airflow over the surface, so that  $e \propto f^{1/2}$  in agreement with the above deduction.

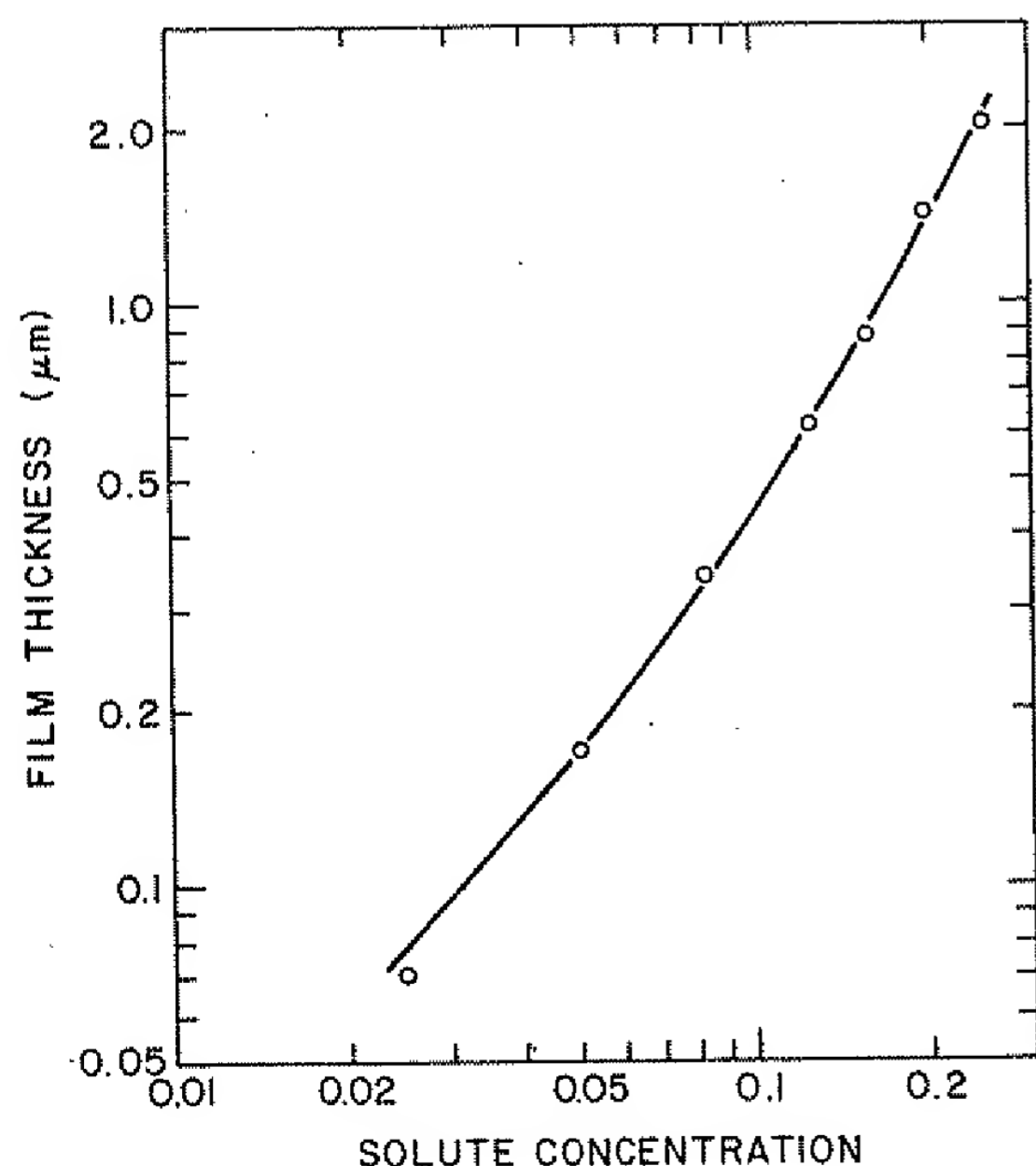


FIG. 5. Film thickness produced at  $f=1000$  rpm as function of the initial concentration of solute Mark II'. The curve is calculated using the parameter values given by Eqs. (12) and (13). The points are experimental.

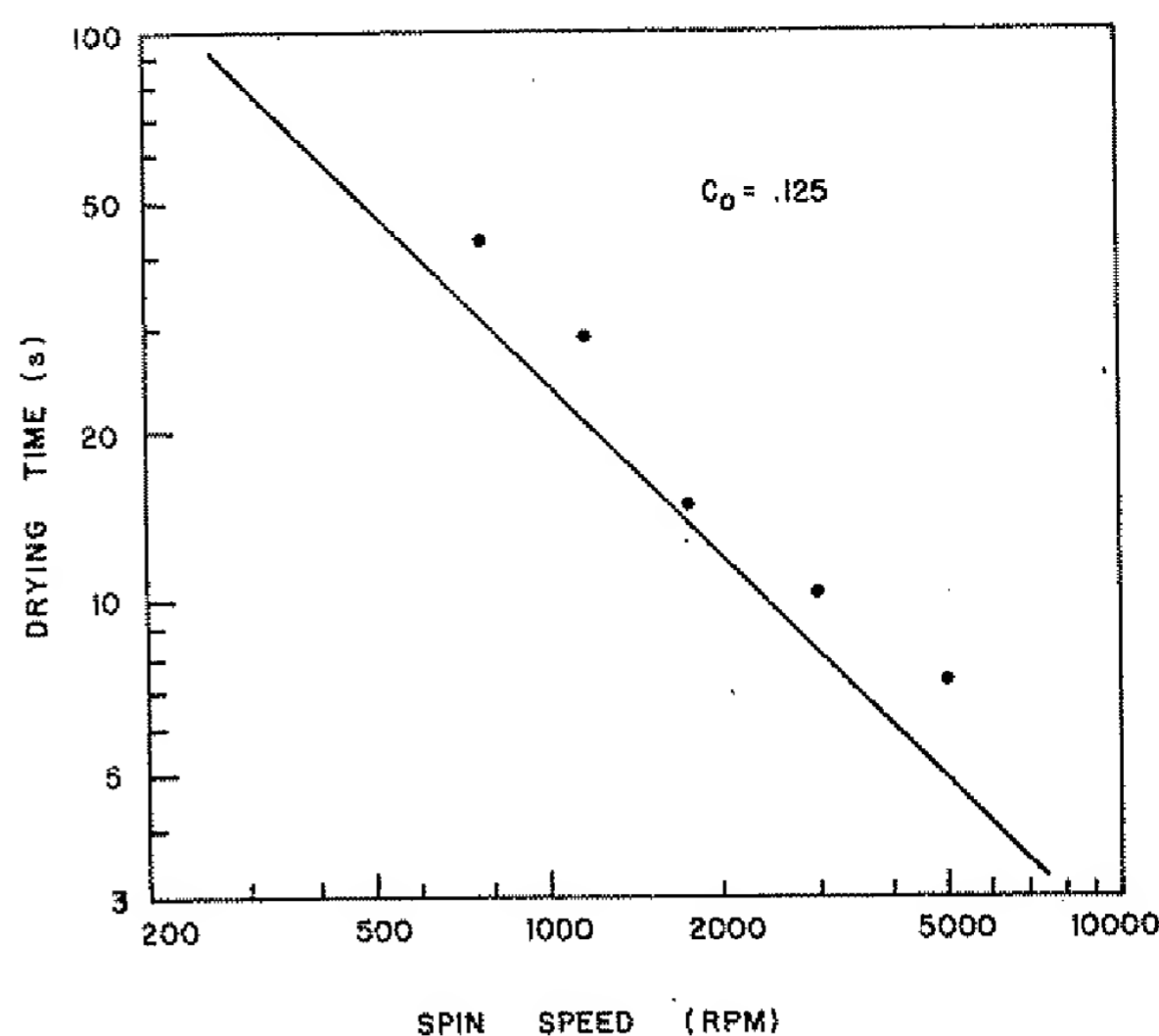


FIG. 6. Drying time versus spin speed for Mark II' with  $c_0 = 0.125$ . The curve is calculated [Eqs. (12) and (13)]; the points are measured through visual observation.

The different slope of the most dilute solution in Fig. 4 cannot be explained readily. The thickness values are quite small, and less accurate, but the effect appears to be real and has been confirmed on large substrates at about the same concentration.<sup>7</sup>

By fitting one point of the Fig. 4 to a corresponding calculated value, we obtain a numerical value of the evaporation rate per unit area ( $f$  is in rpm):

$$e = 6.32 \times 10^{-9} f^{1/2} \text{ m/s}. \quad (13)$$

With this value, we recalculate the predicted film thickness as function of initial concentration. A comparison with the experiment is shown for 1000 rpm in Fig. 5, with good agreement.

As a final check on the model we have been using, we investigated the time it takes for  $h_f$  to be reached. The film was observed for changes in interference colors during spinning. The drying time was taken as that point where the color stops changing. This is a subjective measurement which we could reproduce with 1–2 s variation. In Fig. 6, the experimental data are shown compared to the curve calculated using the appropriate value of  $e$  [Eq. (13)]. There is some difference in the absolute values of time, but the speed dependence is well reproduced, lending further support to the model.

In conclusion, we have described a model of spinning films from solution. It is based on the equations of Emslie *et al.*<sup>1</sup> with the addition of the evaporation of the solvent. The experimental data are well described by this model if the evaporation rate is assumed to vary as the square root of the spin speed.

#### ACKNOWLEDGMENT

I would like to acknowledge the assistance of E. J. Gavalchin in the experimental measurements.

<sup>1</sup>A.G. Emslie, F.T. Bonner, and L.G. Peck, J. Appl. Phys. 29, 858 (1958).

<sup>2</sup>A. Acrivos, M.G. Shah, and E.E. Petersen, J. Appl. Phys. 31, 963 (1960).

<sup>3</sup>A recent paper by B.D. Washo [IBM J. Res. Develop. 21, 190 (1977)] attempts to calculate the thickness of spun films without taking evaporation into account. This is done by making an unrealistic approximation of no or little outward flow. It results in a radial dependence of the thickness [Eq. (8) of their paper], whereas the exact calculation of the

fluid distribution without evaporation predicts a uniform thickness (Ref. 1).

<sup>4</sup>G.F. Damon, *Proceedings of the Second Kodak Seminar on Microminiaturization* (Eastman Kodak Co., Rochester, New York, 1967), p. 36.

<sup>5</sup>O.S. Heavens, *Optical Properties of Thin Films* (Butterworths, London, 1955), Chap. 5.

<sup>6</sup>A.E. Bell (private communication).

<sup>7</sup>L.P. Fox (private communication).

<sup>8</sup>W.G. Cochran, Proc. Cambridge Philos. Soc. 30, 365 (1934).

# ACCUGLASS® T-11

## OVERVIEW

The ACCUGLASS T-11 ( $\kappa = 3.8$ ) Spin-On-Glass (SOG) Series is a family of methylsiloxane polymers used for interlevel and overcoat passivation in the manufacture of integrated circuits.

The ACCUGLASS T-11 series is specially formulated to fill narrow (down to  $0.3\mu\text{m}$ ), high aspect ratio (up to 4) gaps without voids while planarizing multi-level metal devices.

ACCUGLASS T-11 contains 10 wt%  $\text{CH}_3$  (methyl) groups bonded to Si atoms in the Si-O backbone. The specific formulation results in a stable dielectric constant, high crack resistance, excellent gap fill and planarization properties of the cured film.

Thin films of ACCUGLASS T-11 are applied using a commercial coater and cured in a vertical or horizontal furnace to thicknesses up to  $3800\text{\AA}$  (single coat) and  $6000\text{\AA}$  (double coat).

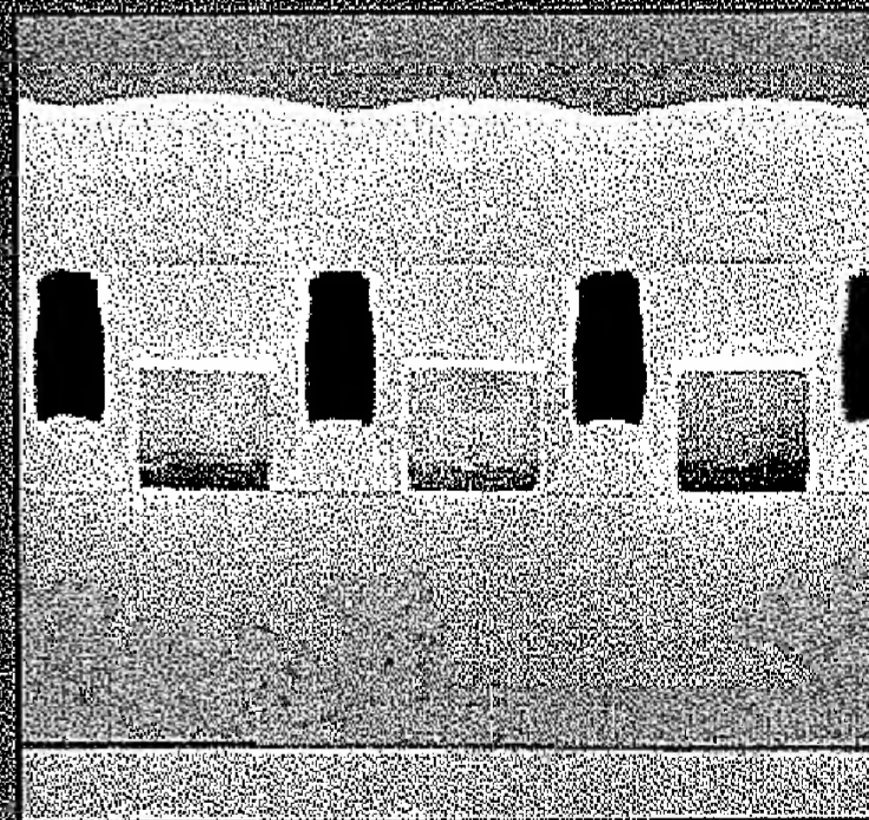
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- Industry proven performance and broad acceptance
- T-11 fills gaps as small as  $0.3\mu\text{m}$
- High thermal stability
- Compatible with hot aluminum and tungsten plug processing
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- Thickness variation within a wafer of less than 1%. Wafer to wafer variation of less than 2%
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- Crack resistance up to  $6000\text{\AA}$
- Good adhesion to top and bottom dielectric layers

## APPLICATIONS

- ILD and PMD Planarization
- Overcoat Passivation
- Gapfill

ACCUGLASS T-11 is suitable for gap fill and planarization of ILD and PMD structures used in multilevel metal IC devices. Typically, partial etchback (PEB) is used for ILD and total etchback (TEB) is used for PMD. ACCUGLASS T-11 can also be used to improve planarization of the final passivation layer.



ACCUGLASS® T-11 planarizes and fills gaps to  $0.35\mu\text{m}$

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From Layer One to Package Done™

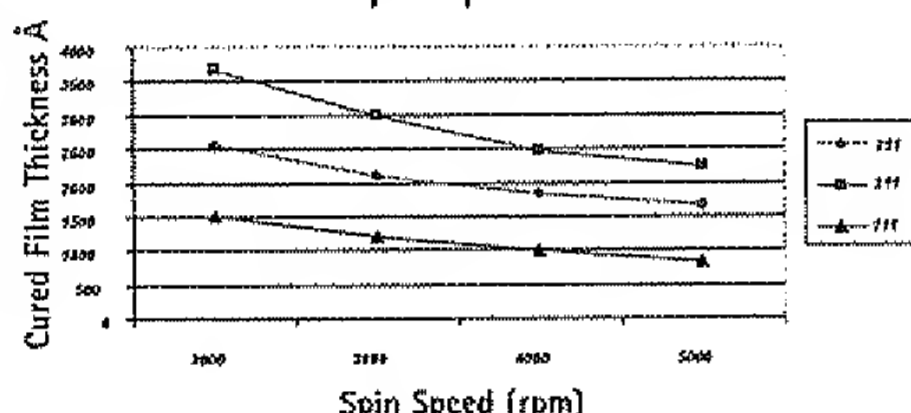
## ACCUGLASS® T-11

### FEATURES

#### Thickness

Product	Thickness Range
111	860Å – 1,500Å
211	1,600Å – 2,600Å
311	2,200Å – 3,800Å

T-11 Spin Speed Curve



#### Film Properties Post Cure

Dielectric Constant @ 1 MHz:	3.8
Tensile Stress:	120 MPa
Refractive Index @ 633 nm:	1.39
Coeff. of Thermal Expansion:	5X10 <sup>-6</sup> K <sup>-1</sup>

#### Material Properties

111 Shelf Life @ 4°C:	12 months
211 Shelf Life @ 4°C:	8 months
311 Shelf Life @ 4°C:	6 months

Shelf life equivalencies @ Room Temperature: 20°C

111 1 Day at RT =	2 days in 4°C Storage
211 1 Day at RT =	5 days in 4°C Storage
311 1 Day at RT =	5 days in 4°C Storage

Bottle sizes available:

125ml, 250ml, 500ml, 1L, 2L, 4L

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<b>Design Search Code</b>	26.17.13 - Letters or words underlined and/or overlined by one or more strokes or lines; Overlined words or letters; Underlined words or letters
<b>Serial Number</b>	73497946
<b>Filing Date</b>	September 4, 1984
<b>Current Filing Basis</b>	1A
<b>Original Filing Basis</b>	1A
<b>Published for Opposition</b>	July 16, 1985
<b>Registration Number</b>	1361262
<b>Registration Date</b>	September 24, 1985
<b>Owner</b>	(REGISTRANT) ALLIED CORPORATION CORPORATION NEW YORK COLUMBIA ROAD AND PARK AVENUE MORRISTOWN NEW JERSEY 07960  (LAST LISTED OWNER) Honeywell International Inc. CORPORATION DELAWARE 101 Columbia Road Morristown NEW JERSEY 07962
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<b>Attorney of Record</b>	David A. Cohen
<b>Description of Mark</b>	THE LINING SHOWN ON THE MARK IS A FEATURE OF THE MARK AND DOES NOT INDICATE COLOR.
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